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JOURNAL OF THE
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Volume 5 MAY, 1938 Number 7

Full-Feathering Propellers*

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Presented at the Power Plants and Propellers Session, Sixth Annual Meeting, I. Ae. S. January 25, 1938

SUMMARY

THE ability to stop an engine from rotating in case of an engine failure is, from the safety standpoint, the greatest asset of the full-feathering propeller. In addition, recent flight tests with bimotored airplanes equipped with feathering propellers have shown the definite improvement that can be obtained, in all phases of single-engined performance, and in airplane control, stability, and also freedom from vibration, from feathering the inactive propeller.

Performance figures for two weight classes of airplanes having identical power plants are presented. The comparison of the single-engined level flight performance, feathered, *vs.* the windmilling condition, shows the definite advantage of the former. The effect on the single-engined rate of climb of feathered and windmilling propellers in high pitch is charted for the heavier of the two classes considered.

Engine oil temperature is found to be the greatest factor affecting the friction horsepower and subsequent drag effects of the windmilling engine-propeller combination. Charts showing variations in friction horsepower with oil temperature are presented.

Full-feathering propellers are recommended for all multi-engined airplanes.

INTRODUCTION

A fully feathered propeller is referred to in this paper as one that has stopped rotating with the blades so highly pitched as to offer minimum drag and to contribute zero windmilling torque to the engine crankshaft.

The past year has brought to the operators of our civil and military airplanes the realization that some quick and positive means of stopping the rotation of the propeller and engine in the case of engine failure is absolutely necessary from the safety standpoint, to prevent possible catastrophic failures of major structural members of the airplane. The critical vibration frequencies of these members occasionally coincide with the period of the heavy forced impulses generated by the windmilling propeller and the disabled engine. When no means are available to stop the engine-propeller combination from rotation, continued windmilling operation often causes structural vibrations so severe as to cause immediate landing of the airplane. Fortunately, in the fourteen cases of emergency landings due to the above causes that have come to the author's attention in the past year or so, no lives were lost and, in the majority of cases, the airplanes escaped serious damage. Many more emergency landings have undoubtedly resulted from the same causes, of which information is not available for this paper. In some of the cases noted the airplanes were able to fly at reduced power, in spite of severe vibration, long enough to reach emergency fields; others had to land immediately, regardless of the terrain, with varying severity of damage to equipment. One airplane was equipped with propeller brakes and was able to reach its destination over water under conditions which otherwise would undoubtedly have resulted in a major catastrophe.

The following discussion considers two weight classes of representative bimotored airplanes having identical power plants: Class 1 of gross weight 10,000 to 12,500 lbs.; Class 2 of gross weight 20,000 to 25,000 lbs.

Notes on the Operation of Feathering Propellers

Simulating emergency conditions in an airplane of Class 2, it is possible to stop a 1000 hp. motor with a feathering propeller in from 10 to 35 sec., depending mainly on the type and design of propeller used, the velocity of the airplane, and other variables to be discussed later. Naturally the lower the velocity of the airplane, the less energy there is in the windmilling slipstream, and the time-to-feather and stop is hence decreased. The conditions tested closely simulated emergency engine stoppages due to loss of oil, slow progressive failures, and the like. Major mechanical failures in engine parts should materially aid in decreasing the time-to-feather and stop.

Of interest are flight tests with existing designs of propeller brakes on engines rated about 1000 hp., showing that it is necessary to slow the airplane down to an indicated air speed below 120 m.p.h. to insure positive stoppage. This velocity cannot then be greatly exceeded and stoppage is not assured unless the brake bands are free from oil. The adverse effect of the braked propeller on performance is shown later. Successful brake tests have been made at low velocities with time-to-stop varying from 7 to 20 sec.

It is desirable to be able readily to feather and unfeather the propeller both on the ground and in the air. This permits checking the operation of the propeller for maintenance purposes and permits training of pilot personnel in the handling characteristics of the airplane in single-engined flight.

In an emergency, the feathering control is first applied. The next action is to shut off the supply of gasoline to the carburetor and engine because of the possible fire hazard. The ignition switch is not normally turned off until after the engine has stopped rotating. In the unfeathering operation, because of the fire hazard and to prevent damage to the engine, the ignition switch should be turned on before the unfeathering control is applied. Care must be taken in unfeathering that the engine and engine oil are not too cold. There is at least one instance where an engine was seriously damaged upon applying the unfeathering control because of cold engine oil. If it is desired to unfeather a propeller after it has been feathered, particularly in cold weather, the engine should be shut off in the feathering operation, using the oil dilution system if the engine is so equipped. In the unfeathering operation there is an enormous starting torque generated by the propeller as it begins to windmill.

It is possible to turn over the engine on the ground with the propeller feathered, but this is not recommended because of high manifold pressures and an extremely lean mixture which normally causes serious detonation. Due to the aerodynamic forces, it is not easy to run the engine in the air with the propeller feathered.

Depending on the single-engined velocity of the airplane, frictional horsepower, propeller pitch distribution, planform, and diameter, the feathering blade angles at 0.75 radius to prevent windmilling in either direction vary normally from 83 to 86°. Depending on the type and design of the propeller, the weight increase for the full-feathering feature varies from zero to about 50 lbs. over the equivalent constant-speed propeller.

From the pilot's standpoint, besides stopping the engine, the outstanding feature of the feathered propeller in single-engined flight of bimotored airplanes is the improvement in control, the airplane handling like a single-engined craft.

Table 1

	Class 1 (10,000–12,500 lbs.)	Class 2 (20,000–25,000 lbs.)
Wing in Bending	480– 520	450–480
Aileron	775– 825	625–675
Fuselage in Torsion	475– 525	350–400
Stabilizer in Bending	825– 875	800–825
Fin in Bending	950–1050	700–740

The Case for Safety

In Table 1 are listed typical critical vibration frequency ranges (c.p.m.) of the major structural components of airplanes in Classes 1 and 2.

It is to be noted that because the smaller airplane is more rigid, the critical frequencies are considerably higher than for the larger airplane. Continuing the thoughts expressed in the introduction, it is seen that in the case of engine failures, where the propeller is windmilling at a slow enough rate, the frequency of the impulses generated by the damaged engine might readily cause forced vibrations in the airplane structure at critical frequencies which might quickly become destructive.

In feathering at cruising velocities and above, the braking action of the propeller is greatly increased and there is usually some noticeable structural vibration as the rotational frequency lowers and passes through the critical frequencies of the main structural members. Experience to date would indicate that the limit for time-to-feather will depend on the severity of this vibration and the strength of the engine-propeller supporting structure necessary to take the high braking loads imposed on the system by the propeller as it feathers. At the present time it appears that about a 10-second time-to-feather would be a reasonable objective for propeller designers and

would be adequate to take care of all emergencies for which it would be possible or desirable to stop the engine.

Available references on engine reliability giving engine miles and hours per engine failure vary considerably.[1,2] A 5-second time-to-feather objective has been proposed by several airline operators, mainly to take care of engine failures during take-off. As take-off operation involves only between $^1/_2$ and $^3/_4$ of one percent of the total engine operation time, this 5-second requirement seems at this stage of the development of full-feathering propellers to be too stringent.[1]

Valuable data exist with airline operators concerning engine failures. A continuous yearly analysis of the number of engine failures, showing percentage of failures during take-off, should be made by some central agency that has access to the necessary data. In addition, further experiments must be made to determine the minimum possible time-to-feather without failure of, or serious damage to, the propeller shaft, engine nose unit, and engine supporting structure.

Performance Comparisons

Recent single-engined flight tests at the Materiel Division, Wright Field, Dayton, Ohio, made with a bimotored airplane in Class 1, gave the following results. (All figures are averages of several flights with the altitude and power being held constant.)

High speed on either engine, with the other propeller feathered, was 187 m.p.h.

High speed on either engine, with the other propeller windmilling, was 175.5 m.p.h.

The windmilling propeller was in high pitch (blade setting 32° at 0.75 radius) at 1425 r.p.m. with the oil-in temperature + 13 deg. C.

The difference in velocity is 11.5 m.p.h., or 6.6 percent, in favor of the feathered propeller.

High speed on both engines at $^1/_2$ power was 195 m.p.h.

It must be noted here that the windmilling runs were made with closed throttle due to danger of carburetor icing with open throttle for the atmospheric conditions prevalent the day of the tests. It will be later shown (Fig. 2) that the friction horsepower would have been appreciably lowered had the throttle been held open. This effect is particularly due to the high windmilling r.p.m. With open throttle the velocity differential would have been lowered to about 5 percent, or 8.9 m.p.h. Note that this airplane has superior performance to that in Class 2 below, and that the percentage increase in performance is considerably greater.

Extensive single-engined flight tests made with a bimotored airplane in Class 2 gave the following results. (All figures are averages of several flights with the altitude and power held constant.)

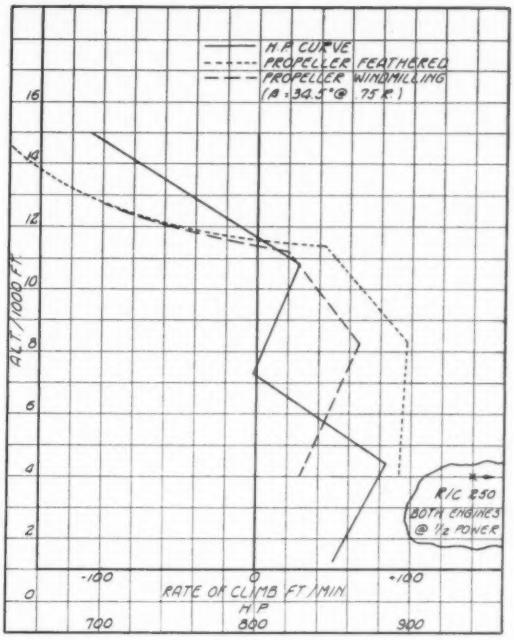

Fig. 1. Rate of climb and horsepower *vs.* altitude curves for Class 2 airplane.

High speed on either engine, with the other propeller feathered, was 138.5 m.p.h.

High speed on either engine, with the other propeller windmilling, was 133.5 m.p.h.

The windmilling propeller was in high pitch (blade setting 34.5° ± 0.5° at 0.75 radius) at 690 r.p.m. with the oil-in temperature +18°C.

The difference in velocity is 5 m.p.h., or 3.7 percent, in favor of the feathered propeller.

High speed on both engines at $^1/_2$ power was 149 m.p.h.

Here there was no appreciable difference in performance between the windmilling with either open or closed throttle. Due to the low windmilling r.p.m. the friction horsepower is about the same for either condition. See Fig. 2.

Of interest is a windmilling test run in low pitch of 17° at 0.75 radius. The loss in velocity was about 20 m.p.h. and the single-engined ceiling could not be obtained because of the engine overheating.

Fig. 1 compares the single-engined ceilings and rates of climb between the feathered and high-pitch windmilling conditions on an airplane in Class 2. The initial slopes of the rate-of-climb curve are typical for engines with two-stage supercharger gear ratios. It is to be noted that the feathered rate of climb up through the critical altitude, while low, is about double the windmilling rate. The rate-of-climb curves below the single-engined ceilings are the result of single-engined saw-tooth climb tests. The negative rate-of-climb curves above the single-engined ceilings are the result of driftdown test runs where the minimum rate of

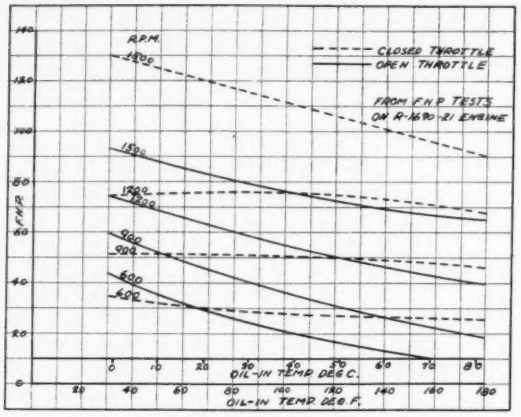

FIG. 2. Variation of friction horsepower with oil-in temperature for R-1690-21 engine.

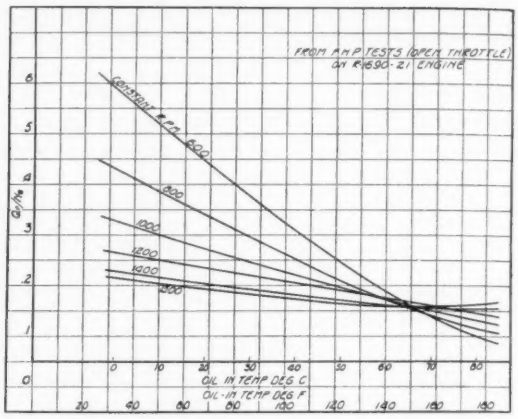

FIG. 3. Variation of Q_f/N_e ratio with r.p.m. and temperature for R-1690-21 engine.

descent was held. Ceilings, once obtained, can be maintained during driftdowns that cannot be reached by climbing. Note that at 4000 ft. altitude the two-engined rate of climb at $^1/_2$ power is 250 ft. per min. Of interest is the fact that single-engined saw-tooth climb tests are much more difficult than two-engined tests because of the relatively low rates of climb and the fact that the velocity for best climb is very critical and must be held within an extremely small range.

Flight test results on three similar bimotored airplanes of gross weights of 18,000, 21,000, and 24,000 lbs. gave the following limits for single-engined ceilings under four different propeller conditions for the inactive engines as noted. All three airplanes had the same power plants and propellers.

(1) The ceilings for windmilling in high pitch with oil temperatures from +10° to +85°C. varied from 7400 to 11,000 ft.

(2) The ceilings for the feathered condition were increased from 200 to 1300 ft. above the high-pitch windmilling ceilings. These ceilings were determined from driftdowns. Due to the relatively low velocities at ceiling for this class of aircraft, the windmilling r.p.m.'s are low and oil temperature does not have the percentage effect that it has with higher velocities and higher windmilling r.p.m.'s.

(3) The ceilings for the braked condition were 1200 to 3500 ft. under the high-pitch windmilling ceilings as determined from driftdowns.

(4) The ceilings for windmilling in low pitch were about 2000 ft. under the braked ceilings.

The airplane of gross weight of 24,000 lbs. had only a 4000 ft. braked ceiling under standard conditions with an initial rate of climb at sea level of only 30 ft. per min. The low-pitch windmilling ceiling would be zero for all practical purposes. In the high-pitch windmilling condition continued operation under extremely cold flying conditions will decrease the ceiling until, as the engine becomes braked, the ceilings will approach the braked ceilings.

It is interesting to note that the first test flight on record using full-feathering propellers was made in 1933 with a Curtiss T-32 Condor of gross weight of 16,800 lbs. Here the feathered propeller gave an increased single-engined ceiling of 1300 ft. over the windmilling condition. This blade setting was 24°, which, in part, explains this relatively large increase in ceiling. The propeller drag due to windmilling at this relatively low blade angle is appreciably greater than normally exists with the increased high-pitch windmilling settings common today.

Published data on negative thrust and torque of windmilling three-blade propellers are based on tests of a powered wind-tunnel model of a single-engined airplane.[3] Results of full scale wind-tunnel tests will shortly be published by the National Advisory Committee for Aeronautics extending the data given by Hartmann.[4] These full scale tests show remarkable agreement with those of reference 3, the differences probably being explained by the difference in design of the propellers used and the difference in the test setups.

Flight-glide tests with a single-engined airplane with the propeller both feathered and windmilling showed no measurable difference in performance for windmilling blade settings at 0.75 radius in excess of 35°. Test results referred to in reference 5 substantiate these settings. These windmilling tests, however, were made with hot engine oil so that the appreciable drag effects due to increasing friction horsepower with decreasing oil temperature were not evaluated. The only use for a full-feathering propeller on a single-engined airplane would be to stop the motor from rotation in case of engine failure and to increase the gliding distance. Because of the adverse drag effect due to decreasing oil temperature on a windmilling engine, it can be readily seen from study of the preceding performance data on bimotored airplanes that the feathering propeller is valuable in improving single-engined performance for all multi-engined airplanes in

general. The increasing windmilling drag as oil temperatures drop from operating temperatures to the prevailing atmospheric temperatures causes increasing yaw in single-engined flight which causes additional body and tail surface drag. There is a vicious circle of decreasing performance as the windmilling flight continues. No attempt will be made in this paper to evaluate quantitatively the differences in drag between feathered and windmilling single-engined performance, other than the effect of oil temperature on friction horsepower and the subsequent effects on negative thrust and torque coefficients for the windmilling propeller as it overcomes the friction torque of an inactive engine. A method of evaluating the other drag effects occurring in single-engined flight of bimotored airplanes has been thoroughly presented in reference 6.

Figs. 2 and 3 give the effect on friction horsepower and friction torque for a geared, single-row, air-cooled radial engine of 1690 cu.in. displacement, with variation in oil temperatures, r.p.m., and open and closed throttle. These data can quite accurately be extended for engines of different horsepowers by assuming friction torque and horsepower to vary proportionally to the displacement. The various coefficients used for presenting the data are defined as follows from reference 3.

$T_c = T/\rho V^2 D^2$
$Q_c = Q/\rho V^2 D^3$
$Q_n = Q_c(V/nD)$
Q_f = Friction torque (lb.ft.)

where

T = Effective thrust. Negative sign indicates force in the direction of a drag force
Q = Torque (lb.ft.). Negative sign indicates propeller turning engine
V = Velocity (ft. per sec.)
D = Propeller diameter (ft.)
β = Blade angle at 0.75 radius
h = Altitude (ft.)
ρ = Air density (slugs per cu.ft.)
n = Revolutions per second of propeller
N = Propeller r.p.m.
N_e = Engine crankshaft r.p.m.
Δ = Engine displacement (cu.in.)

The data in Figs. 2 and 3 are for friction conditions at sea level and were made on a dynamometer stand. Under windmilling flight conditions at altitude the cylinder temperatures would be somewhat lower than the oil-in temperatures. Piston friction, which is believed to be about 30 percent of the total friction horsepower of an engine, would therefore be slightly increased. Due to the decrease in pumping losses at altitude, the friction horsepower is slightly decreased. As these corrections are relatively slight and tend to cancel each other, there is no correction for altitude for the data presented except that for oil-in temperature as plotted.

Under emergency windmilling conditions the throttle would normally be open so as to have minimum friction torque. Windmilling conditions for flight testing or training might require closed throttle conditions because of the danger of carburetor icing. Fig. 2, therefore, gives sufficient data to allow the proper evaluation between open and closed throttle.

Comparing the windmilling r.p.m.'s of the Class 1 and Class 2 airplanes, it is seen from Fig. 2 that as airplane performance increases the windmilling propeller will have an increasingly greater drag effect.

The lower velocities of the Class 2 airplane will cause lower windmilling r.p.m.'s, and thus less friction torque. Note that at the windmilling r.p.m.'s for the Class 2 test the friction horsepower changes little from open to closed throttle. This change is accentuated, however, as the windmilling r.p.m.'s increase as in the Class 1 tests.

It is interesting to note here that the position of the stopped blades in the feathered condition made no measurable difference in performance (Fig. 10, reference 3). This is to be expected because the drag of the feathered propeller is here a very small part of the total drag of the airplane.

The following data were chosen to demonstrate the use of the charts in Figs. 2, 3, and 4. These particular data were chosen because a positive check of the windmilling blade angle was made by landing the airplane with the propeller locked in the high-pitch position.

Test of airplane in Class 2:

h = 8000 ft.
ρ = .00187
D = 11.5 ft.
β = 37.7° at .75 radius (windmilling)
V = (left engine on; right feathered) = 138.8 m.p.h. at 803 hp.
V = (left engine on; right windmilling) = 132.8 m.p.h. at 800 hp.
N_e = 600; N = 412; Δ = 1820
Oil temp. = +8°C.

The throttle on the windmilling engine was closed. Here the difference in velocity was 6.0 m.p.h., or 4.5 percent. As the horsepower required varies as the cube of the velocity, this represents roughly 14 percent, or 112 hp. Thus 912 hp. would be required under the windmilling condition to bring the velocity up to 138.8 m.p.h. equal to the feathered condition.

From Fig. 2, the f.hp. = 32.5 × 1820/1690 = 35 hp.
Q_f = hp. × 33,000/2πN_e = −306 lbs.ft.

Had the test been made with open throttle Q_f could have been determined and checked from Fig. 3, where

$Q_f = Q_f/N_e \times 1820/1690 \times N_e$
$Q_e = -.00278$
$V/nD = 2.47$, $nD/V = .405$
From Fig. 4 for $nD/V = .405$ at $\beta = 37.7°$
$T_c = -.014$

$Q_c = -.0031$ (This happens to be a fairly accurate check of the above computed value of $-.00278$. Differences may be because the reference data are from tests on a single-engined high-wing airplane model and the comparison here is with a conventional nacelle-wing mounting.)

From $T_c = -.014$, $T = -131$ lbs.

The power required to overcome this drag = 46.5 hp. This must necessarily be greater than f.hp. from Fig. 2 = 35 hp., because the windmilling propeller is inefficient as a windmill. Even so, the value of 46.5 hp. does not seem high enough, because a fast running propeller even designed as a windmill gives only 75 percent of the maximum possible power at its optimum operating condition, and the efficiency is only $52^1/_2$ percent.[7]

For lack of better data assume that the value of 46.5 hp. represents fairly accurately the power necessary to overcome the drag of the windmilling propeller. Subtracting 46.5 hp. from 112 hp. leaves 65.5 hp., representing the power necessary to overcome the added airplane drag due to yaw and other causes.[6]

Test data from the airplane in Class 1 do not at all check the values for negative thrust and torque as does the example in Class 2. The windmilling blade angle would seem to be too high by several degrees. The data were taken with great care and are hard to refute. A recheck will be made as soon as equipment becomes available. Values for friction torque and horsepower computed from Figs. 2 and 3 seem reasonable. The difference in velocity of 6.6 percent when cubed represents 21.2 percent of the power, or 182 hp. As the friction horsepower from Fig. 2 is 110 hp., the difference to be accounted for as airplane drag and propeller losses is 72 hp.

No good reason for the discrepancies between wind-tunnel and flight tests can be given at this writing, except that the former do not evaluate the effect of yaw, nacelle-wing position, and the other factors affecting the flow through the windmilling propeller. An inspection of the steep slope of the curves in Fig. 4 for Q_c *vs.* nD/V for the higher blade angles shows how critical this region is for high advance ratios. It is believed that the method outlined here is as accurate as any for determining and estimating windmilling engine friction drag values. Extensive flight tests must be made to furnish data to enable the proper evaluation of the other drag effects occurring in partial-engined flight.[6]

Effect of Temperature on Oil Viscosity

Quantitative values for the effect of temperature on engine friction torque and horsepower have been given. It is believed of interest here to show how temperature changes affect oil viscosity which has such a great bearing on mechanical engine-friction losses. Fig. 5 gives

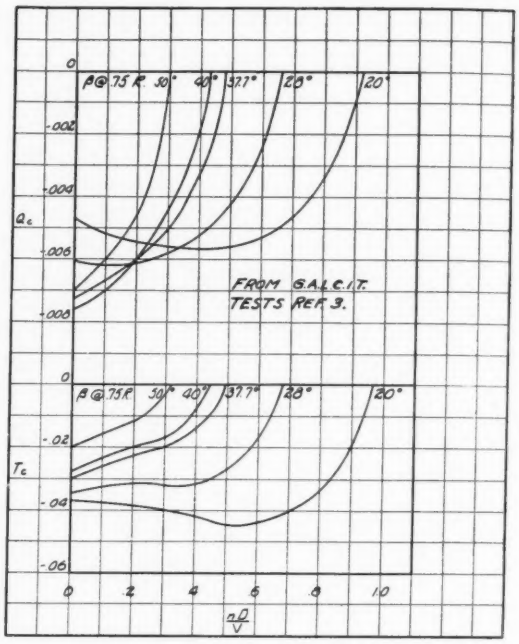

FIG. 4. Negative torque and thrust coefficients for three-bladed propeller from California Institute of Technology tests.[3]

approximate viscosity changes for different grades of oil and variation with temperature. Grade 120 is the standard oil for normal flying and about 80 percent of all Air Corps consumption is of this grade. Grade 77 is the standard winter oil for use in temperatures of 0°F. and below. Engines kept in heated hangars so that the starting problem is not critical can use Grade 98 oil if the temperatures are not too extreme.

The three crosses on the Grade 120 line represent "easy cranking" for +40°F., "minimum temperature for normal start" for +30°F., and "minimum start under ideal conditions" for +20°F. Engines left out overnight will be "frozen" with temperatures from +10° to 0°F., depending upon the mechanical condition of the engine. Even if the engine can be "broken loose" at these low temperatures, heating will be necessary for a start unless oil dilution is used. It can be seen from these data that the windmilling propeller can readily approach and become "braked" with continued operation at extremely cold temperatures.

Conclusions

Recent flight tests have shown that the use of feathering propellers is advantageous for all multi-engined airplanes for three general reasons:

(1) A full-feathering propeller permits a relatively quick and positive stoppage of rotation of an engine in an emergency regardless of the velocity or attitude of flight of the airplane. Primarily this assures greater flight safety.

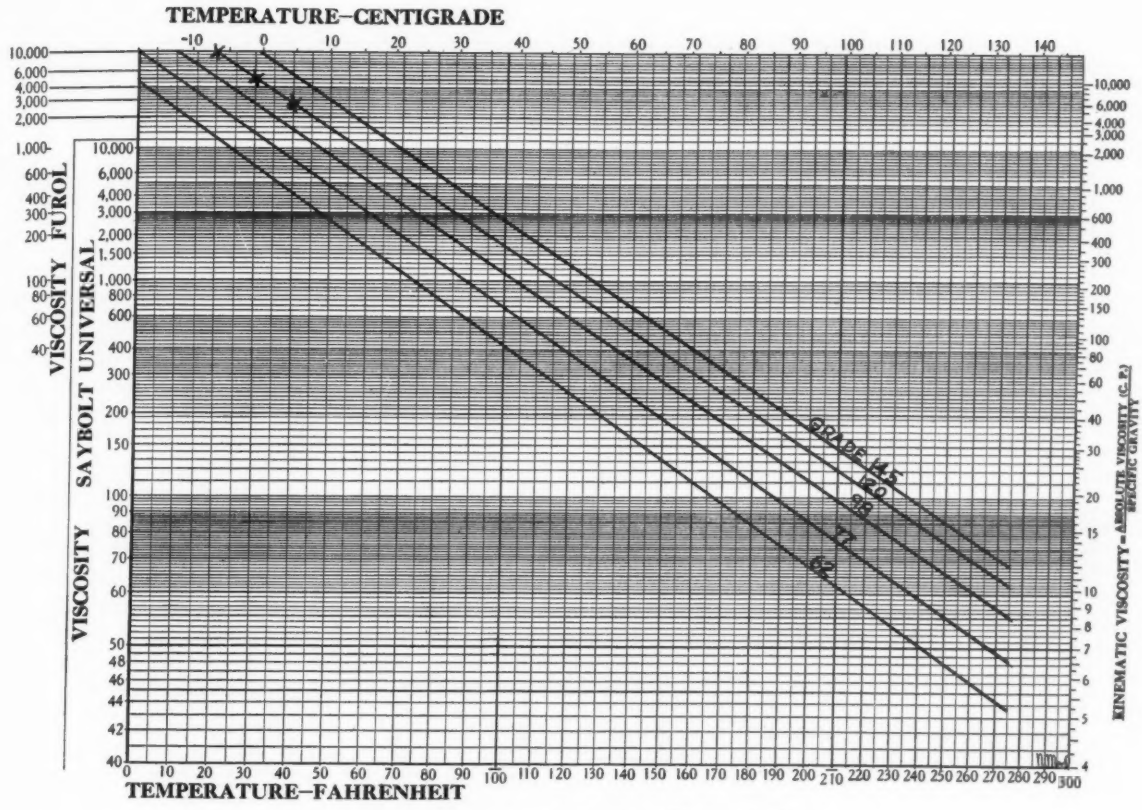

FIG. 5. Variation of oil viscosity with temperature.

(2) The increase in single-engined performance for the feathered over the windmilling or braked conditions is shown by increased ceilings, increased rates of climb, and faster level flight at all altitudes.

(3) Due to lower drag and decreased disturbance, there results a freedom from vibration, an improvement in stability, and an increase in control in single-engined performance for the feathered over the windmilling condition.

The percentage gain in single-engined performance for the feathered propeller over the windmilling condition increases as airplane performance increases.

Considering single-engined ceiling, climb, and high-speed performance, the order of merit of performance is as follows for the propeller conditions as listed.

(1) Full feathered.

(2) Windmilling in high pitch with hot engine oil.

(3) Windmilling in high pitch with decreasing engine oil temperature.

(4) Braked condition.

(5) Windmilling in low pitch.

The effect of engine oil temperature on friction horsepower can be determined for representative engines from data presented.

The development of full-feathering propellers is one of the most valuable contributions in years to the safety in operation and aerodynamic improvement of airplanes.

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* The views expressed in this report are those of the author and not necessarily of the War Department. The author wishes to acknowledge the aid of Louis H. Enos in the collection of data for this paper.

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A Study of Design Conditions for Tricycle Landing Gears

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SUMMARY

SOME design conditions that will permit the inherent safety features of the tricycle landing gear to be more or less fully utilized are set forth. The paper covers the definitions of the landing conditions, reasons for the choice of certain values, and includes incidental references to the application of the conditions in determining the structural loads.

The proposed conditions are based on vertical velocities, rates of drift, pitching motion, etc., that have been observed in landing tests or that seem likely from particular experiences with conventional landing gears. In addition, the probable use and method of operation of different classes of airplane have been considered. The ultimate criterions, however, must await further experience with the tricycle landing gear and full-scale tests of the loads developed under operating conditions.

INTRODUCTION

The tricycle landing gear, because of its many outstanding advantages over the conventional gear with two main wheels and tail wheel or tail skid, is being applied quite generally to airplanes at the present time. The general characteristics of the tricycle gear have been covered to a considerable extent in a paper by Fred E. Weick,[1] and a study of the stability and shimmy of the castering wheel has been recently made by the N.A.C.A.

In the application of the tricycle landing gear to airplanes, the designer is immediately faced with the question of what design loads to use for this type of gear. It is apparent that the design conditions will depend upon how many of the inherent capabilities of the tricycle gear the designer intends to make use of, not only for taxying but also for landing. The design conditions will also depend upon the type of airplane and the purposes for which it is to be used.

An attempt has been made in the present paper to set forth some design conditions that will permit the inherent safety features of the tricycle gear to be more or less fully utilized. These conditions are not proposed as *minimum* requirements for safety; it is assumed that such minimum requirements will be essentially the same for both conventional and tricycle types, and that they are covered by the existing regulations. The additional ruggedness required of the landing gear over the minimum is of course a matter for decision based on the intended service of the airplane. Hence no attempt is made here to settle the question of whether it is desirable in any individual case to adhere rigorously to the conditions as given in view of possible weight penalties, and so forth.

GENERAL CLASSIFICATIONS FOR DESIGN CONDITIONS

On the basis of the purposes for which they are to be used and corresponding possibilities of operation of the different types, airplanes may be divided into a few general classes according to weight. For the present study three classes of airplanes are assumed: (1) under 2000 lbs.; (2) 2000–10,000 lbs.; and (3) 10,000–100,000 lbs.

Light airplanes: 1- and 2-place. Class (1) may be considered to consist almost entirely of the type popularly known as the "light" airplane. It is interesting to note that, according to bulletins of the Bureau of Air Commerce, during the years 1935, 1936, and the first half of 1937, airplanes in this class (1- and 2-place) averaged about 64 percent of all of the domestic civil aircraft produced during those periods. Hence, it may be assumed that, for the present at least, airplanes in this class will be the most numerous and, for several reasons, will be flown largely by private owners and by persons not so experienced as professional pilots. In these cases, in particular, it appears quite likely that the landing gear will be called upon to withstand many unusual operating conditions and should therefore be designed to take the greatest possible advantage of its capabilities.

Medium-sized airplanes: 3- to 7-place. Class (2) is assumed to consist principally of the types of airplane used by the sportsman pilot and for small transport operations. During the years 1935, 1936, and the first half of 1937, airplanes in this class (3- to 7-place) averaged about 28 percent of all of the domestic civil aircraft produced during those periods, so that this class represents the second largest group in number. The airplanes in this class will most likely be flown by fairly well-trained pilots and the landing gear, except for emergencies, will ordinarily not be called upon to perform under conditions as severe as those specified for class (1).

Large airplanes: 8-place and up. Class (3) is assumed to be composed almost entirely of the large

TABLE 1
Factors Considered in Design Conditions for Tricycle Gears

Factor	Class 1 Airplanes (under 2000 Lbs.)		Class 2 Airplanes (2000–10,000 Lbs.)		Class 3 Airplanes (10,000–100,000 Lbs.)	
	Maximum Value	Average Value	Maximum Value	Average Value	Maximum Value	Average Value
Vertical velocity	20 ft. per sec.	(a) 15 and (b) 5 ft. per sec.	15 ft. per sec.	(a) 10 and (b) 5 ft. per sec.	12 ft. per sec.	(a) 7 and (b) 3 ft. per sec.
Side drift velocity	20* or 15† ft. per sec.	15* or 5† ft. per sec.	10* or 5†	0	Same as class 2	Same as class 2
Angle of pitch	(a) Attitude at normal gliding speed + 7 ft. per sec. and (b) attitude at which tail structure strikes ground	(a) Attitude at normal gliding speed (b) Attitude at maximum lift in level flight	Same as class 1	Same as class 1	(a) Attitude for descent at 12 ft. per sec. (b) Tail structure strikes ground	Attitude at maximum lift in level flight
Bank angle	Attitude at which wing touches ground (not in excess of 15°)	0°	Same as class 1 except need not exceed 10°	Same as class 1	5°	Same as class 1
Braking	$\mu = 1.10$	(a) $\mu = 0.55$ and (b) $\mu = 0$	Same as class 1	Same as class 1	Same as class 1	Same as class 1
Ground obstruction	1.0 g. load backward on nose wheel	0	Same as class 1	Same as class 1	Same as class 1	Same as class 1
Curving on ground	Sidewise skid	0	Same as class 1	Same as class 1	Same as class 1	Same as class 1

* When 2 control. † When 3 control.

transport airplanes. The airplanes in this class (8-place and up) averaged about 5 percent of all of the domestic civil aircraft produced during 1935, 1936, and the first half of 1937 and so compose the smallest group numerically of the three classes. These airplanes will be flown by highly skilled pilots and, for the purposes for which they are intended, will probably impose the least severe conditions of any on the landing gear.

Discussion of Detail Design Conditions

Table 1 lists the various factors that enter into the proposed design conditions. A single condition will include a maximum of one factor combined with average values of the others. The values given are proposed simply as a starting point, subject to revision as additional knowledge and experience are gained. Their selection is based, for the most part, on the results of landing and taxying tests of various conventional and unconventional airplanes made by the N.A.C.A. staff and others. What seemed to be appropriate maximum and mean values, based on the tests and on probable operating conditions, were listed without regard to the relative severity of the different conditions in actually determining the landing-gear design. Thus some of the combinations will be found to be not critical.

Assumptions involving the simultaneous occurrences of several extreme or emergency conditions were avoided since the probability of such occurrences is small with respect to the probability of a single extreme condition. Such assumptions would, therefore, not lead to a rational distribution of the strength of the landing gear. The specifications given consist generally of one extreme condition combined with mean values of other conditions.

Maximum Vertical Velocity Condition

The first condition considered is that of maximum vertical velocity. According to the foregoing plan this factor is taken as extreme and combined with several other average conditions. Using as example the numerical values given in Table 1 for the light airplane class, the following combination is taken:

Vertical velocity, 20 ft. per sec.
Side drift velocity, 5 ft. per sec.
Angle of pitch, attitude at normal minimum gliding speed.
Bank angle, 0°.
Braking, $\mu = 0.55$.
Ground obstruction, 0.
Curving, 0.

The foregoing condition corresponds to a landing made without leveling-off or "flaring"; the attitude

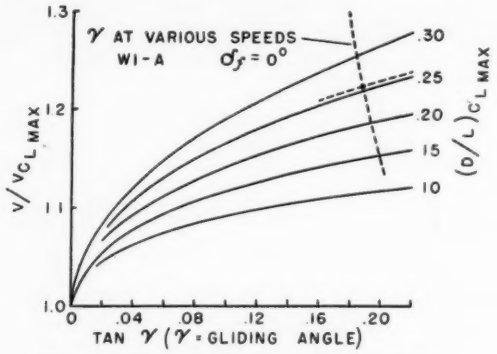

FIG. 1. Minimum gliding speed of an airplane.

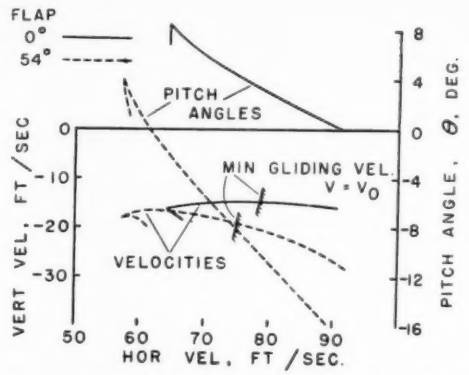

FIG. 2. Velocity and attitude curves for W1-A airplane in power-off steady glides.

assumed is that for a normal glide landing with flare. The vertical-descent velocity of 20 ft. per sec. is not considered sufficiently high to provide a reasonable margin of safety for such landings as regular occurrences. Experiments made at the N.A.C.A. laboratories have indicated that descent velocities up to 30 ft. per sec. might be encountered in these landings under exceptional circumstances.[2] The 20 ft. per sec. limit is considered, however, to provide a sufficient margin of safety for unflared landings if they do not occur too frequently, or in very gusty air.

The pitch attitude is of importance in unflared landings to determine whether the nose wheel or the main wheels will strike the ground first. In order to define the attitude at normal gliding speed, it is considered that the approach will be made at a speed somewhat in excess of the actual landing speed ($V_{C_{Lmax}}$) on account of the additional lift required if a flared landing were made. Fig. 1 (taken from reference 3) shows the minimum excess speed in the glide required for a normal flared landing with different drag-lift ratios at maximum lift and different angles of approach. These curves were calculated on the basis that the maximum possible lift is utilized at every instant during the leveling-off or flaring process, and hence they represent an idealized minimum of excess speed.

The results of some N.A.C.A. full-scale wind-tunnel tests of the W1-A airplane will serve to illustrate the use of this chart in defining the pitch attitude. Fig. 2 shows the velocities and attitudes of the W1-A airplane in gliding flight as deduced from the test data. The ratio of drag to lift at $C_{L_{max}}$ as called for on Fig. 1 may be taken as the ratio of vertical to horizontal velocity at the stalling speed. A curve of gliding angle against $V/V_{C_{Lmax}}$ may then be prepared from Fig. 2. The intersection of this curve with the appropriate curve of Fig. 1 gives the value of the minimum gliding speed, $V_0/V_{C_{Lmax}}$. Fig. 2 shows this speed for two settings of the flaps. Results of flight tests of this airplane agree roughly with these points.

Fig. 3 and 4 show the W1-A airplane approaching the ground at attitudes corresponding to the minimum gliding speeds, with two different flap settings. It will be noted that, in the flap-down condition, the nose wheel would appear to strike the ground before the main wheels do. In this condition it is essential that the front shock absorber resist the impact with sufficient force to reduce the vertical velocity of the *nose* of the airplane to zero before the end of its stroke is reached. Of course, the vertical velocity of the airplane as a whole will ordinarily not be entirely absorbed by the front wheel mechanism. In order to determine the loads in the front wheel or, conversely, to determine a design of the front shock strut and tire that will not lead to excessive loads, a calculation including the pitching rotation induced by the landing load may be necessary.

The resistance characteristics of a shock absorber are usually given in terms of the mass supported and the velocity of impact for simple drop tests. The conditions in the nose-first landing (Fig. 3) may be converted to conditions in an equivalent straight drop test of the front wheel and strut. The velocity of impact in the drop test will be the vertical velocity of the landing (*i.e.*, 20 ft. per sec. in this case). The mass used, however, will not be the entire mass of the airplane, since this mass is not carried directly over the front wheel. Taking account of the moment of inertia of the airplane, mk_Y^2, and the distance of the front wheel ahead of the center of gravity, l_2, the equivalent mass for straight drop tests works out to be

$$m' = \frac{m}{1 + (l_2/k_Y)^2}$$

and depends on the ratio of the moment arm of the front wheel to the radius of gyration of the airplane in pitching. The conditions in this drop test will apply to the actual landing up to the moment the rear wheels strike the ground. If R is the resisting force developed in the foregoing drop test, the angular velocity and hence the angle of the airplane at any instant may be computed from the time integral of R; *i.e.*,

$$mk_Y^2 q = \int_0^t Rl_2\,dt$$

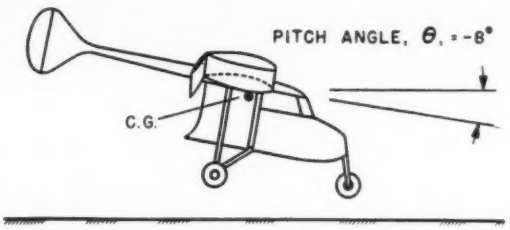

FIG. 3. Landing with maximum vertical velocity with flaps down ($\delta_f = 54°$), W1-A airplane.

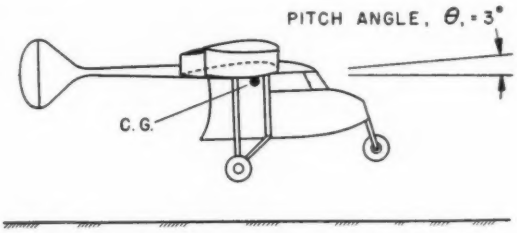

FIG. 4. Landing with maximum vertical velocity with flaps up ($\delta_f = 0°$), W1-A airplane.

where q is the angular velocity. Also, the vertical velocity of the center of gravity will be reduced during the time of action of the front shock strut by the amount

$$m\Delta w = \int_0^t R dt$$

In the present example it will not be necessary to investigate the impact of the main wheels in the nose-down landing since the impact will obviously be greatest in the nose-up condition (Fig. 4) when the main wheels strike first. During the primary absorption of impact in the nose-up landing, there will be no load on the front wheel. A rotation in pitch will be built up, however, by the braking force at the rear wheels. The result is that sometime during the absorption of the landing shock the front wheel will strike the ground. The loads thus developed in the front-wheel mechanism may be computed from its resistance characteristics by formulas similar to those already given.

Under normal conditions a skilled pilot will not permit a drift to continue right up to the point of contact with the ground even when landing in a strong cross wind. For airplanes with the tricycle gear it seems reasonable, however, to allow for some drift velocity in normal landings. The maximum drift velocity is, of course, based on conditions that might be encountered when the pilot makes no correction for the cross wind.

In the case of 2-control operation the pilot has no direct means for neutralizing wind drift. Hence in these cases the conditions are intended to provide a sufficient margin of safety for uncorrected drift landings as regular occurrences.

Since the wheels are considered locked in the present landing condition ($\mu = 0.55$), the existence of a drift

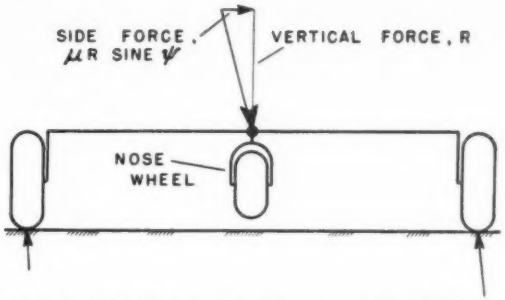

FIG. 5. Distribution of load between main wheels in drift landing with brakes locked.

velocity means only a slight inclination of the braking load and a slight inequality in the distribution of the landing load between the two main wheels. If the front wheel has no brake and is free to caster, its side load will be relieved by the turning motion set up. Fig. 5 illustrates the division of load between the main wheels in a drift landing.

MAXIMUM DRIFT VELOCITY

The drift allowance is set at 15 ft. per sec. for airplanes in the light class and is arbitrarily reduced for the larger airplanes on the assumption that these latter will be flown by pilots of greater skill. It may be desirable, however, to increase the drift velocity for the large airplanes in order to reduce their dependence on available runways. The other factors entering into the maximum drift condition are taken as:

Vertical velocity, 5 ft. per sec.
Pitch angle, attitude for level flight at maximum lift.
Bank angle, 0°.
Braking condition, 0.

Since the simultaneous occurrence of extreme conditions is not considered, the vertical velocity in the drift landing will be taken as the greatest likely to be encountered in normal landings in rough air, *i.e.*, 5 ft. per sec. This value is based on observations of such landings reported in previous tests.[4] (The actual value there observed was 3.6 ft. per sec.)

The full use of wheel brakes in a landing is not considered to represent an extreme or accidental condition. Thus landings with wheels locked and with wheels free are considered equally likely.

In the case of drift landings, the greater side load will be built up in the landing with brakes off. With regard to this point, which may be somewhat difficult to visualize, it should be noted that the sliding of the tires on the landing surface represents a case of what is termed "dry friction"; that is, the friction force is assumed to be proportional to the load carried and to be directed along the line of the resultant sliding, although it is independent of the rate of sliding. When the landing is made with wheels locked, the resultant sliding is along the line of motion of the airplane relative

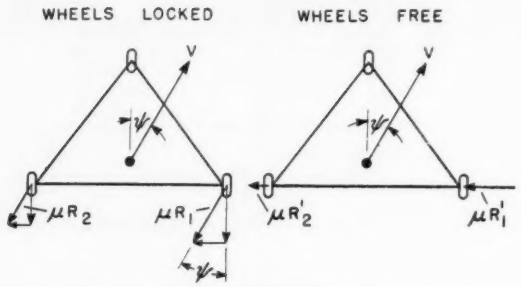

FIG. 6. Sliding forces in drift landings. (a) Landing with wheels locked. (b) Landing with wheels free.

to the ground and is therefore inclined to the plane of the wheels by an angle ψ. The side thrust on the wheel is then equal to the vertical load carried by the wheel multiplied by the coefficient of sliding friction ($\mu = 0.55$) and by the sine of the angle of drift. The rate of sliding in this case is equal to the relative velocity of the airplane and the surface.

Considering the other circumstance, landing with brakes off, it is seen that there can be no component of sliding in the plane of rotation of the wheel because no force in this direction can be transmitted to the bottom of the tire through the axle (neglecting the short period of angular acceleration of the wheel). The resultant sliding must then take place at right angles to the plane of rotation. The resultant force must also act this way and, although the resultant rate of sliding is now less than in the case of brakes locked, the resultant force developed will not be less since it is independent of the rate. Fig. 6 illustrates the two occurrences.

An interesting point in connection with directional stability arises from consideration of Figs. 5 and 6. If the main wheels are near the c.g., the airplane may show greater directional stability in the drift landing with main wheels locked than with wheels free. Fig. 5 shows that the wheel on the right carries an increased load during the absorption of impact in a landing with drift to the right. With brakes locked, a component of this additional load tends to drag the right wheel back, reducing the drift angle. In the landing with wheels free, the actual side pressure on the wheels is increased, although the forces act through a relatively short lever arm. Referring to the figures it is seen that, if the wheel track is wide and the backward placement of the main wheels with respect to the c.g. is small, greater directional stability will be apparent with brakes on; whereas the converse will be true if the main wheels are at a relatively large distance behind the c.g.

One of the primary advantages of the tricycle gear is its ability to negotiate drift landings safely. In view of this fact it may become feasible to lower the present requirement of landing area, possibly to the extent of using a single runway. In this event, higher margins of safey may be required in the drift landing condition, as mentioned previously.

MAXIMUM-PITCH CONDITION

The maximum-pitch condition represents an extreme or accidental landing in which the vertical descent velocity is not so great as the maximum but in which the airplane strikes the ground at (1) an extreme nose-down, or (2) an extreme nose-up attitude. The vertical-descent velocity is taken as the higher of the two mean velocities listed (*i.e.*, only slightly less than the maximum), while the pitch angles represent extreme conditions. The following combination is assumed for the light airplane class:

Vertical velocity, 15 ft. per sec.
Drift velocity, 5 ft. per sec. (if 3-control).
Bank angle, 0°.
Braking condition, $\mu = 0.55$.

The maximum nose-down attitude in pitch is the attitude at which the airplane might be descending toward the ground at a speed somewhat in excess of that required for the landing flare. This speed is arbitrarily taken as 5 ft. per sec. above the minimum indicated by Fig. 1. (See points marked on Fig. 2.) The maximum nose-up attitude is usually limited by the structure and may be taken as the angle at which the tail of the airplane strikes the ground. It seems reasonable to propose, however, that the angle need not exceed 5° to 7° beyond stalling in any case. Except for the different attitudes and rate of descent assumed, this landing condition is essentially the same as the maximum vertical velocity condition.

MAXIMUM-BANK CONDITION

A landing with considerable bank can occur if one side of the wing is caused to stall prematurely when making contact. The maximum bank that it is necessary to consider in the *landing-gear* design will be that at which one wing tip touches the ground. In case this angle is excessive, 15° may be taken as the upper limit for airplanes of the light class.

The vertical-descent velocity in this landing is the value likely to be encountered in a normal landing in rough air, *i.e.*, 5 ft. per sec. The other factors assumed are as follows:

Drift velocity, 5 ft. per sec. (if 3-control).
Braking condition, $\mu = 0.55$.

As far as the absorption of landing shock is concerned, the bank condition bears some similarity to the nose-down conditions previously discussed. Although during the first part of absorption of the impact, only one of the shock struts is in action, this strut will not build up the resistance that it would if the entire mass of the airplane were carried directly over the wheel. For a straight drop test of shock strut and wheel to

approximate this condition the velocity of impact would be 5 ft. per sec. and the mass used would be

$$m' = \frac{m}{1 + (l_3/2k_X)^2}$$

where m is the mass of the airplane, l_3 is the lateral wheel base, and k_X is the radius of gyration of the airplane about the X axis. As in the case of a straight landing with a gear that spreads as it deflects, a side force equal to the vertical force times the coefficient of tire friction ($\mu = 0.55$) will be developed at the wheel. This force will normally be taken by the lateral bracing of the gear.

Taxying Over Ground Obstructions

The maximum ground obstruction impact that the nose wheel should be capable of withstanding is even more a matter for practical experience than are the previous conditions.

It has been observed during tests made by the N.A.C.A. that the greatest accelerations during normal landings with conventional gears were usually less than those developed in the ground runs. The greatest acceleration reported in these tests[4] was 2.8 g.

A rearward load on the nose wheel equal to the weight of the airplane is probably a practical minimum strength requirement. It may be desirable to incorporate a fore-and-aft shock absorber in the design of the front structure so that much more severe conditions could be met.

Turning on the Ground

The maximum sidewise acceleration that can be developed by turning on the ground is that necessary to overcome the sliding friction of the tires. The greatest value of the coefficient of friction likely to be encountered should be used here. Tests have shown values slightly higher than $\mu = 1.0$ for rubber tires on rough concrete surfaces, although $\mu = 0.55$ appears to be a suitable mean value for most conditions. A value of 1.10 is assumed for the present condition. The load developed in the gear is simply 1.10 times the weight of the airplane acting from the side and divided between the nose wheel and the rear wheels in inverse proportion to their distances from the c.g. It is obviously desirable that the wheel tread be sufficient to prevent overturning in this condition.

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Student Branches

University of Michigan. Two meetings of this Student Branch of the Institute were held during the months of February and March. At the meeting held on February 24, motion pictures were shown of tests carried out on a model of the hull of the new Sikorsky four-engined patrol bomber. After the motion pictures were shown, Professor M. J. Thompson spoke on the Sixth Annual Meeting of the Institute, and gave a résumé of those papers which he thought held the greatest interest for the students present. At the second meeting, held on March 17 in the West Engineering Building, plans for the spring program for the Branch were outlined. E. W. Conlon, Instructor in the Department of Aeronautical Engineering, was introduced as speaker of the evening. Mr. Conlon spoke on practical problems of aircraft engineering.

Oregon State College. An organization meeting of this newly formed Student Branch of the Institute was held on April 20. The following officers were elected: Professor B. F. Ruffner, Honorary Chairman; George Drakeley, Chairman; Everett Denton, Vice Chairman; and Keith Kruchek, Secretary-Treasurer. A committee was appointed to draw up by-laws for the Student Branch, and plans were outlined for future activities of the Branch.

Polytechnic Institute of Brooklyn. The first regular meeting of this Student Branch was held on April 8 in the South Building of the Institute. Talks dealing with articles appearing in the current issues of the Journal were given by three of the members. Robert Kidder spoke on the investigations which were being conducted on the flow of air near the boundary layer of an airship; Anthoney Pfister spoke on the use and advantages of the new airplane slide rule; and George Wunderlin spoke on a simple method of locating the aerodynamic center of an airfoil. A short discussion followed each of the talks.

Rensselaer Polytechnic Institute. Two meetings of this Student Branch were held recently. At the first, held on February 17, R. Aldrich, manager of the Troy Municipal Airport, and guest speaker for the evening, spoke on Blind Flying. Informal discussion followed Mr. Aldrich's talk. At the second meeting, held on Thursday, March 10, B. L. Wiggin, Associate Meteorologist and Chief Forecaster of the U. S. Weather Bureau at Newark Airport, spoke on Meteorology.

Laminar Boundary Layer Based on a Minimum Theorem

RICHARD H. SMITH, *Massachusetts Institute of Technology*

Presented at the Aerodynamics Session, Sixth Annual Meeting, I. Ae. S.
January 26, 1938

Introduction

THE classical treatment by Blasius which develops the velocity profile and thickness of the laminar boundary layer on an open air-washed surface under constant pressure, although rigorous as developed, rests upon the rather severe assumption of similitude of velocity profiles. In recent years, both theoretical and experimental evidence has arisen which makes the validity of this assumption open to question. Aside from the fact that direct laboratory measurements of the velocity profiles do not show strict similitude and that careful indirect studies based on the heat which is carried away by the boundary layer of a hot surface indicate profiles more nearly parabolic than Blasian near the beginning of the layer, the chief difficulties with the Blasian profile are that it is out of balance with respect to energy, and that it fails to give any indication of flow transition from the laminar to the turbulent phase.

These objections to the Blasius treatment, which virtually exhausts the possibilities of the Navier-Stokes' equation as a basis for analysis, together with a growing need for new help in handling not only laminar layers under constant pressure, but laminar and turbulent layers under gradients of pressure as well, led the author about four years ago to examine the possibility of approaching these problems from the standpoint of certain minimum theorems. The present paper is a progress report on only that part of these exploratory studies which has to do with laminar boundary layer under constant pressure and over surfaces of zero curvature.

The Minimum Theorem

When any surface, such as a sharp edged plane, glides steadily through a viscous fluid, the towing energy required reappears in the boundary layer wake at the trailing edge in two forms, the conservative or kinetic energy in the wake motion and the dissipative or lost energy in the form of heat. If the shearing stresses which built up the boundary layer over the surface did so without dissipation, the whole of the towing energy would reappear in the wake in the form of kinetic energy of the wake motion. The mechanical energy of towing would then be converted conservatively into kinetic energy of fluid motion. This of course cannot occur. However, it is possible, without violating the boundary conditions on the flow, for the velocity distribution across the boundary layer to so arrange itself everywhere that the flow is as nearly conservative as possible. Substantial evidence that this minimum condition does in fact control the velocity distribution across boundary layers is not difficult to find.

It is well known that a steady electric current so divides itself in a network of conductors as to cause the least possible dissipation or departure from conservative flow.[1] The analogy between an electrical network of parallel conductors carrying a steady current under a given voltage and a boundary layer stratified by parallel and insulating stream surfaces carrying a steady momentum under a given pressure is not difficult to draw, at least in the case of tube or parallel plane flows, and leads to the conclusion that, in these cases certainly, the velocity distribution across the flow is also that which gives minimum dissipation. It will be shown presently that the minimum condition imposed upon these flows does lead, in fact, to parabolic velocity distribution which is known from elementary considerations to be the correct one. The extrapolation of the minimum theorem to cover open boundary layers for which the validity of the theorem is not so easily demonstrated seems to be allowable in view of the fundamental form of the theorem and of its proven validity in these special electric and hydrodynamic cases.

The minimum theorem, requiring the nearest possible approach to conservative flow, imposes two restrictions upon open boundary layers. The shearing stresses which build up the flow must not only generate the kinetic energy of the boundary layer with a minimum of dissipation but also must convey this energy along the layer with a minimum of dissipation. Only then is the ratio of the dissipation heat to the kinetic energy, or the departure from conservative flow, a minimum everywhere. Since the shearing stresses in the fluid both generate the kinetic energy in a given elementary mass and transport the mass along the layer, by the same mechanism, the two restrictions are equivalent to one. If one chooses the second restriction, which is by far the more important, as the controlling one, the flow theorem giving everywhere a minimum departure from conservative flow, can be stated as follows: "For viscous flows, such as boundary layers, which are generated and maintained by shearing stresses, the ratio of

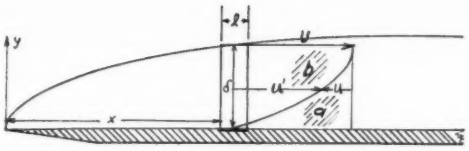

FIG. 1.

the energy dissipated by the flow in passing through a given local space, to the flow energy passing, is a minimum."

If insignificant terms are neglected, the energy dissipated per unit volume per unit time is proven in works on hydrodynamics[2] to be $\mu(\partial u/\partial y)^2$, where μ is the molecular coefficient of viscosity and $\partial u/\partial y$ is the local velocity gradient. Hence if the local space is a segment of the boundary layer, $l\delta$, Fig. 1, any elementary volume of the fluid will dissipate the energy $\mu(l/u)(\partial u/\partial y)^2$ in passing through the space while it will carry through the energy $(\rho/2)u^2$. The velocity and energy values must, of course, be those which are generated by the shearing stresses, namely the deficit values corresponding in the figure to the area "a" rather than the complementary values which correspond to the area "b."

The problem now is to find $u = f(y)$ which will make $\mu(l/u)(\partial u/\partial y)^2$ a minimum for a given $(\rho/2)u^2$, or, in the terminology of the calculus of variations, to minimize,

$$(1/u)(\partial u/\partial y)^2 + au^2 \tag{1}$$

where, a, is an arbitrary factor having the dimensions of $(lv)^{-1}$ Eq. (1), being a function, f, of u and m, if $m = \partial u/\partial y$, is a minimum[3] when,

$$(\partial f/\partial u) - (\partial/\partial y)(\partial f/\partial m) = 0 \tag{2}$$

Then

$$-(m^2/u^2) + 2au - 2[\partial/\partial y)(m/u] = 0 \tag{3}$$

Now

$$(d/du)(m^2/u) = [2mu(dm/du) - m^2]/u^2$$

or, since

$$m(dm/du) = (dm/dy) = m'$$

$$(d/du)(m^2/u) = 2(m'/u) - (m^2/u^2)$$

But,

$$2(\partial/\partial y)(m/u) = 2(m'/u) - 2(m^2/u^2)$$

therefore

$$(d/du)(m^2/u) = (m^2/u^2) + 2(\partial/\partial y)(m/u)$$

Eq. (3) then becomes,

$$(d/du)(m^2/u) = 2au$$

giving after integration,

$$m^2 = (du/dy)^2 = au^3 + bu \tag{4}$$

If the deficit kinetic energy is zero, as occurs near the leading edge of a sharp-edged plane lying parallel to the stream, then $a = 0$ and Eq. (4) reduces simply to,

$$du/dy = \sqrt{bu}$$

giving,

$$y = 2\sqrt{u/b} + c \tag{5}$$

If, further, the boundary conditions on Eq. (5) are $u = 0$, when $y = \delta$, and $u = U$ when $y = 0$ (see Fig. 1), then $c = \delta$ and $b = 4(U/\delta^2)$ and Eq. (5) reduces to the familiar parabolic profile,

$$u/U = [1 - (y/\delta)]^2 \tag{6}$$

Finally, if the value of b is substituted in Eq. (4) and $u/U = \bar{u}$, $y/\delta = \bar{y}$ and $(a/4)U\delta^2 = H$, Eq. (4) becomes

$$d\bar{u}/d\bar{y} = 2\sqrt{\bar{u} + H\bar{u}^3} \tag{7}$$

which integrates to the laminar velocity profile equation,

$$2\bar{y} = \int_0^{\bar{u}} d\bar{u}/\sqrt{\bar{u} + H\bar{u}^3} \tag{8}$$

The value H in Eqs. (7) and (8) is an arbitrary energy parameter of the form $CU\delta^2$ where C is a constant. At flow separation, where $d\bar{u}/d\bar{y} = 0$ and $\bar{u} = 1$ at the surface, H, by Eq. (7), obviously has the value, -1. The general value of H may then be expressed in terms of its separation value as,

$$H = -U\delta^2/U_s\delta_s^2 \tag{9}$$

where the subscript, s, refers to separation. No restriction has yet been imposed upon the pressure or velocity outside the boundary layer.

Eq. (8) is an elliptic integral whose evaluation, although tedious, is quite straightforward after certain trigonometric transformations are made to agree with the nomenclature of the standard tables of elliptic integrals.[4] Evaluations of Eq. (8) have been made for a spread of H values from $+1$ to -1 in increments of 0.1, although only the negative values will be used here. Since these evaluations constitute in themselves a rather long auxiliary tabulation in mathematics and are not, therefore, directly a part of the present study, they will be omitted in the present treatment and only the final resulting velocity contours, $\bar{u}$ *vs.* $\bar{y}$ will be given.* When these contours are tabulated and plotted, one obtains the family of curves given in Fig. 2. The contour $H = 0$ is a parabola, the contour for $H = -1$, as noted above, is the separation profile, and lying between the two is the range of H which is of interest here.

* The author will be glad to answer any questions concerning these mathematical computations or to lend his original tables for reference.

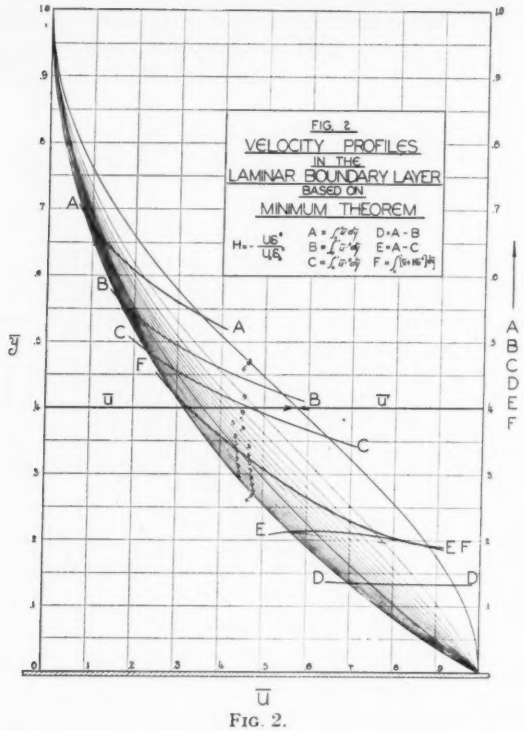

FIG. 2.

Six velocity profile form factors will be needed presently, five of which are defined in terms of the complementary velocity $\bar{u}'$ and one in terms of the deficit velocity $\bar{u}$, Fig. 1, namely,

$$A = \int_0^1 \bar{u}'d\bar{y} \qquad D = A - B$$

$$B = \int_0^1 \bar{u}'^2 d\bar{y} \qquad E = A - C$$

$$C = \int_0^1 \bar{u}'^3 d\bar{y} \qquad F = \int^1 (\bar{u} + H\bar{u}^3)d\bar{y}$$

These factors have also been evaluated from the tables for Fig. 2 and drawn across the H contours in the figure.

Application to Laminar Boundary Layer under Constant Pressure

Consider first the momentum and energy balance in the boundary layer, making use of the form factors A to F defined above. In Fig. 3 the changes of mass, momentum, and kinetic energy within the segment of the boundary layer of unit width which is enclosed between δ_1 and δ_2 and between the wind or Ψ = constant line through δ_2 and the plane, are as follows.

For mass changes,

$$(\text{mass/sec.})_1 = \rho U\delta_1 A_1 + \rho Uh$$

$$-(\text{mass/sec.})_2 = \rho U\left(\delta_1 + \frac{\partial \delta_1}{\partial x}dx\right)\left(A_1 + \frac{\partial A_1}{\partial x}dx\right)$$

$$= \rho U\delta_1 A_1 + \rho U\left(\delta_1\frac{\partial A_1}{\partial x} + A_1\frac{\partial \delta_1}{\partial x}\right)dx$$

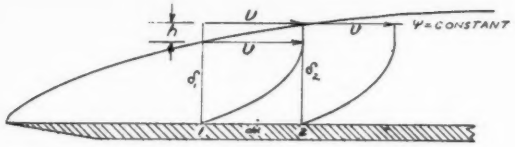

FIG. 3.

Since the mass change must be zero by continuity,

$$h = \left(\delta\frac{\partial A}{\partial x} + A\frac{\partial \delta}{\partial x}\right)dx$$

For momentum changes,

$$(\text{mom./sec.})_1 = \rho U^2\delta_1 B_1 + \rho U^2 h$$

$$-(\text{mom./sec.})_2 = \rho U^2\delta_1 B_1 + \rho U^2\left(\delta_1\frac{\partial B_1}{\partial x} + B_1\frac{\partial \delta_1}{\partial x}\right)dx$$

The net change of momentum is therefore,

$$\Delta(\text{mom./sec.}) = \rho U^2\left[h - \left(\delta\frac{\partial B}{\partial x} + B\frac{\partial \delta}{\partial x}\right)dx\right]$$

$$= 2q\left(\delta\frac{\partial D}{\partial x} + D\frac{\partial \delta}{\partial x}\right)dx$$

$$= 2qD\frac{\partial \delta}{\partial x}dx \qquad (10)$$

since $q = (\rho/2)U^2$ at the outer limit of the boundary layer and since by Fig. 2, D is a constant.

For energy changes,

$$(\text{energy/sec.})_1 = (\rho/2)U^3\delta_1 C + (\rho/2)U^3 h$$

$$-(\text{energy/sec.})_2 = \frac{\rho}{2}U^3\delta_1 C_1 + \frac{\rho}{2}U^3\left(\delta_1\frac{\partial C_1}{\partial x} + C_1\frac{\partial \delta_1}{\partial x}\right)dx$$

The net change of energy is then,

$$\Delta(\text{energy/sec.}) = \frac{\rho}{2}U^3\left[h - \left(\delta\frac{\partial C}{\partial x} + C\frac{\partial \delta}{\partial x}\right)dx\right]$$

$$= qU\left(\delta\frac{\partial E}{\partial x} + E\frac{\partial \delta}{\partial x}\right)dx$$

$$= qUE\frac{\partial \delta}{\partial x}dx \qquad (11)$$

since, by Fig. 2, the form factor E is also essentially constant.

The treatment will now be restricted to the case of constant pressure. When so restricted, the equilibrium of forces requires that Eq. (10) equal the surface friction, and the balance of energies requires that Eq. (11) equal the dissipation. Since the surface friction is,

$$\tau_0 = \mu\left(\frac{\partial u}{\partial y}\right)_{y=0} = \mu\frac{U}{\delta}\left(\frac{\partial \bar{u}}{\partial \bar{y}}\right)_{\bar{y}=0} = 2\mu\frac{U}{\delta}\sqrt{1+H}$$

$$= 4(\nu q/U\delta)\sqrt{1+H} \qquad (12)$$

by Eq. (7), and since the dissipation of energy per second per unit area is,

$$(\text{diss./sec.}) = \mu \int_0^{\delta} \left(\frac{\partial u}{\partial y}\right)^2 dy = \mu \frac{U^2}{\delta} \int_0^1 \left(\frac{\partial \bar{u}}{\partial \bar{y}}\right)^2 d\bar{y}$$

$$= 4\mu \frac{U^2}{\delta} F$$

$$= 8 \frac{\nu q}{\delta} F$$

Equilibrium of forces and energies gives, respectively, the two independent boundary layer equations,

$$\delta d\delta = 2(\nu/UD)\sqrt{1 + H}\, dx \quad \text{for force,}$$

$$\delta d\delta = 8(\nu/UE) F dx \quad \text{for energy,}$$

which integrate to,

$$\delta^2 = \frac{4\nu}{UD} \int_0^x \sqrt{1 + H}\, dx \quad \text{for force} \qquad (13)$$

$$\delta^2 = \frac{16\nu}{UE} \int_0^x F dx \quad \text{for energy,} \qquad (14)$$

The compatibility of Eqs. (13) and (14) will be examined presently, after finding H and F as functions of x.

The value of H for cases of constant pressure, is $H = -(\delta/\delta_s)^2$, by Eq. (9). As a first approximation let $H_1 = -(\delta/\delta_s)^2 = -(x/x_s)$, based on the Blasius parabolic thickness relation. Eq. (13) then gives as a first approximation,

$$\delta_1^2 = \frac{4\nu}{UD} \int_0^x \sqrt{1 - \frac{x}{x_s}}\, dx$$

$$= \frac{8\nu}{3UD} x_s \left[1 - \left(1 - \frac{x}{x_s}\right)^{3/2}\right]$$

Since, at separation, $\delta_{1s}^2 = (8\nu/3UD)x_s$, as a second approximation, $H_2 = [1 - (x/x_s)]^{3/2} - 1$. Substituting H_2 in Eq. (13) and integrating again, gives as a third approximation, $H_3 = [1 - (x/x_s)]^{7/4} - 1$, and so on. When these approximations are carried to the limit, H is found to be simply,

$$H = (x/x_s)^2 - 2(x/x_s) \qquad (15)$$

Eq. (15) shows that the velocity profile is parabolic at the beginning of the boundary layer, since $H = 0$ for $x = 0$. As one goes downstream H increases negatively and finally reaches -1 at separation. The corresponding velocity profiles for the various H values are seen in Fig. 2. The variation of H with x/x_s, given by Eq. (15), is shown in Fig. 4. It should be noted that H is given only in terms of the separation x_s which is still unknown and which must be found experimentally or be otherwise determined before H is finally known as a function of x alone.

Having evaluated H as a function of x/x_s, Eqs. (13) and (14) can be integrated. Substituting Eq. (15) in Eq. (13) gives,

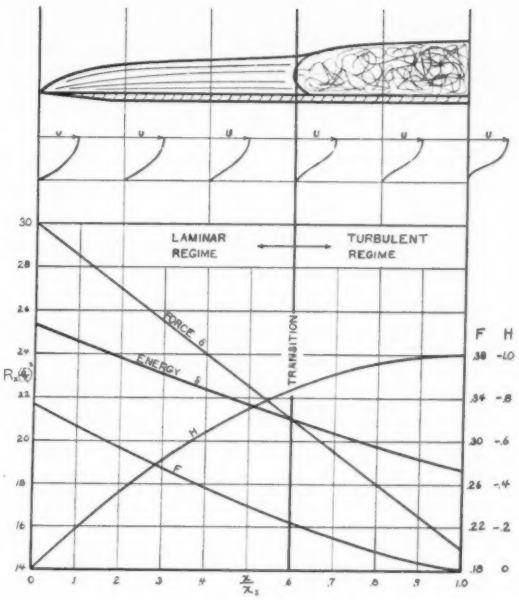

FIG. 4.

$$\delta^2 = \frac{4\nu}{UD} x_s \int_0^{x/x_s} \left(1 - \frac{x}{x_s}\right) d\left(\frac{x}{x_s}\right)$$

$$= 2 \frac{\nu}{UD} x_s \left[2 \frac{x}{x_s} - \left(\frac{x}{x_s}\right)^2\right]$$

from which,

$$R_x \left(\frac{\delta}{x}\right)^2 = \frac{2}{D}\left(2 - \frac{x}{x_s}\right)$$

Since by, Fig. 2, $D = 0.133$, the boundary layer thickness for force equilibrium is,

$$R_x(\delta/x)^2 = 15[2 - (x/x_s)] \qquad (16)$$

which is a linear relation in x, beginning at the leading edge with the value 30 and ending at separation with the value 15, Fig. 4.

Similarly, since H is known as a function of x/x_s by Eq. (15), and since the dissipation form factor, F, is known as a function of H, Fig. 2, F is known as a function of x/x_s, Fig. 4. By simple graphical integration of the areas under the F curve in Fig. 4, the integral $\int_0^{x/x_s} F d(x/x_s)$ in Eq. (14) can be easily evaluated for various values of x/x_s. Finally rewriting Eq. (14) in the form,

$$R_x \left(\frac{\delta}{x}\right)^2 = \frac{16}{E} \frac{x_s}{x} \int^{x/x_s} F d\left(\frac{x}{x_s}\right)$$

and substituting, $E = 0.210$, from Fig. 2, it is found that the boundary layer thickness which gives energy balance at the various positions, x/x_s, has the values given by the $R_x(\delta/x)^2$ curve, labeled "energy δ," in Fig. 4.

It is seen from the figure just referred to that at the beginning of the boundary layer the layer giving force equilibrium is about 9 percent thicker than the layer giving energy equilibrium. Also as one goes downstream, the difference in thickness decreases, passes through zero at $x/x_s = 0.6$, and then becomes negative, indicating that the boundary layer for force equilibrium then becomes the thinner one. The crossing of the boundary layer thickness lines has an important significance which will now be examined.

It is clear that if a boundary layer should thicken throughout, the kinetic energy which is released per unit time in a given segment will increase while the energy which is dissipated in the segment in the same time will decrease. Such a thickening would therefore release in a layer in which the kinetic energy was previously in balance with normal dissipation, an excess of energy which must be disposed of in some other way. Since there can be only one boundary layer, namely the one giving force equilibrium, Fig. 4 shows that there must be an excess of energy in that part of the layer between $x/x_s = 0$ and $x/x_s = 0.6$ and a deficiency of energy between $x/x_s = 0.6$ and $x/x_s = 1.0$. It is easy to see how a small amount of excess energy, such as is found here, can be absorbed. For example, it is known experimentally that the deep sub-layers never flow exactly streamwise, as is assumed in laminar flow, but tend to assume also lateral random motions. Such lateral motions would add, of course, to the pure laminar dissipation and tend to absorb the energy excess. Other minor distortions of the theoretical laminar flow may also occur, and probably do, particularly over the upstream region where the shearing stresses are high, which would further increase the normal dissipation. In any event a boundary layer giving energy balance as well as force equilibrium for the region extending downstream to $x/x_s = 0.6$ from the leading edge is entirely possible, and is in agreement with all that is now known from experiment. Beyond $x/x_s = 0.6$, however, the situation is quite different.

For that part of the boundary layer lying downstream $x/x_s = 0.6$, the minimum possible energy dissipation, namely, that associated with the normal laminar flow which is theoretically smooth and straight, is found to exceed the kinetic energy released by the thickening of the layer. Such a regime is obviously physically impossible.

Since normal laminar flow cannot exist beyond $x/x_s = 0.6$, one must assume that the laminar regime breaks up at this position and is replaced by an entirely different regime, namely the turbulent one, in which the energy released will again be equal to, or more than, that dissipated. Otherwise the continuation of the boundary layer would be impossible. This result gives not only a new definition of the transition from laminar to turbulent flows, but also a new understanding of turbulence itself.

Results

It may be well, finally, to compare the results which have been obtained from the minimum theorem treatment, one by one, with experiment and with the present-day understanding of transition and separation. Beginning at the leading edge and ending with separation, the following is found:

(1) According to the present development, the velocity profile at the leading edge is parabolic. The surface stress, τ_0, produced by a parabolic velocity profile is, by Eq. (12),

$$\tau_0 = 2\mu(U/\delta) = 4q(x/\delta)R_x^{-1} = (4/\sqrt{30})qR_x^{-1/2} = 0.730qR_x^{-1/2}$$

since from Fig. 4, $R_x(\delta/x)^2 = 30$, at $H = x = 0$. In the Blasius theory, $\tau_0 = 0.664qR_x^{-1/2}$ which is just 10 percent less than the τ_0 found in the minimum treatment. Probably the most reliable experimental results on plane, constant pressure, boundary layers at very low values of R_x, or very near the leading edge, are those of Fage and Falkner[5] who measured with great care the heat dissipated from thin narrow metal foils stretched edgewise in the wind. Through the analogy which exists between heat and momentum transfer across the boundary layer, a definite correlation exists between the heat dissipated and the surface friction. When the friction of the foils was computed, the computed values were found to exceed the theoretical values, based on the Blasius velocity profile, by 10 or 12 percent. When the computed friction, however, is based on the parabolic velocity profile, as given by the minimum theorem development, the agreement is very satisfactory.

(2) The laminar velocity profiles between the beginning of the boundary layer and the transition point, which are measured in the laboratory, always show, when drawn in the same composite diagram, a certain spreading both above and below the Blasius profile. Fig. 5, for example, gives the laminar velocity profiles as measured by Hansen[6] on a glass plate in an open-jet constant-pressure airstream. Similar spreading of the profiles are found by Dryden[7] and others. As has been seen, the velocity profiles, as given in the analysis based on the minimum theorem, vary from the parabolic form at the leading edge, to the $H = -0.84$ profile, Fig. 2, at transition. These two limiting profiles are also drawn in Fig. 5, and, except for scattered points, show that the measured data fall fairly well within the $H = 0$ to $H = -0.84$ band. The Blasius profile runs midway in the group as shown.

(3) The minimum theorem treatment shows how a stable laminar layer can maintain the random lateral motions which have been observed in the deep sub-layers as well as other departures of the theoretically smooth and straight laminar flow which inevitably occur due to disturbances of one kind or another. Any such

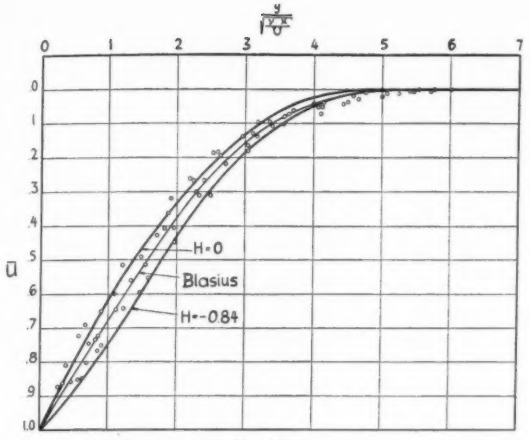

FIG. 5.

motion which is superimposed upon the normal laminar flow will, of course, add to the normal flow dissipation, and hence increase the total dissipation in the boundary layer. So long as the energy available is more than that dissipated by normal shearing, as is found in the present analysis for x/x_s values up to 0.6, such observed lateral and irregular flowing is not only possible but necessary if the boundary layer is to be in energy balance.*

Another finding, related to the one just discussed, is that any added disturbances in the normal laminar flow must tend to raise the whole length of the "energy δ" curve in Fig. 4. The result of course is a pronounced advance of transition, which again is in complete agreement with experiment.

(4) The minimum theorem treatment further shows, for plane laminar layers under constant pressure, that there is flow transition at a point 0.6 of the distance from the starting edge to the separation point. This finding is in complete agreement with the present understanding of separation and transition.

(5) The laminar flow surface stresses from the present study are by Eqs. (12) and (16),

$$\tau_0 = 4q\sqrt{1+H}\,(x/\delta)R_x^{-1}$$

$$= 4q\left(1-\frac{x}{x_s}\right)\left[15\left(2-\frac{x}{x_s}\right)\right]^{-1/2}R_x^{-1/2}$$

$$\frac{\tau_0}{q} = \frac{4}{\sqrt{15}}\left[\left(1-\frac{x}{x_s}\right)\Big/\left(\sqrt{2-\frac{x}{x_s}}\right)\right]R_x^{-1/2}$$

Hence the surface friction intensity varies from $\tau_0/q = 0.730\,R_x^{-1/2}$ at the leading edge to $\tau_0/q = 0.350\,R_x^{-1/2}$ at transition, where $x/x_s = 0.6$, and, of course, would become zero at separation if the laminar regime were to go that far. The Blasius stress, $\tau_0/q = 0.664\,R_x^{-1/2}$, lies between the leading edge and the transition values and corresponds approximately to the $H = -0.35$ profile in this treatment.

(6) In the case of steady laminar flow in a circular pipe or between parallel planes, the flow regime of course is the same at all positions along the flow. Separation, therefore, is infinitely far removed and H by Eq. (15), is zero everywhere. The velocity profile for these flows consequently reduces to the simple parabolic form, Eq. (6), which is known to be correct from elementary considerations.

(7) Although for constant pressure layers, the separation point is never reached because of the intervention of transition, the separation point could, of course, be reached if the pressure over the plate were rising. Since the profiles of Fig. 2 are valid for laminar flows under any pressure fields, we should perhaps compare here the general separation profile found in Fig. 2, with those found by other methods, even though our present study is restricted to constant pressure fields. Probably the most reliable evaluation of the separation profile is that made by von Kármán and Millikan.[8] A very good separation profile derived by these methods will be found in Doenhoff's paper in which he applies the von Kármán-Millikan treatment to the elliptic cylinder.[9] When the von Kármán-Millikan separation profile, which is given by Doenhoff in Fig. 7 of the reference cited, is compared with the separation profile $H = -1$ of Fig. 2, the two curves are found to be practically identical. They would be entirely indistinguish-

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* It is noteworthy in this connection that the Blasius profile, which by the assumption of similitude has the same form everywhere, is out of balance with respect to force or energy or both, depending upon the boundary layer thickness relation used. The first five form factors for the Blasius profile have the values, $A = 0.712$, $B = 0.606$, $C = 0.543$, $D = 0.106$, $E = 0.167$. The dissipation factor corresponding to F will be separately computed.

In the Blasius treatment (see Professor L. Bairstow's paper on "Skin Friction," Journal of the Royal Aeronautical Society, Vol. 29, No. 169, January, 1925)

$$\partial u/\partial y = 1.98(U/\delta)e^{-\alpha}$$

giving as the dissipation per sec., per unit area,

$$\text{diss./arc./unit area} = 3.96\mu\frac{U^2}{\delta^2}\int_0^\delta e^{-2\alpha}dy =$$

$$7.84q\frac{\nu}{\delta}\int_0^\delta e^{-2\alpha}d\left(\frac{y}{\delta}\right)$$

When integrated the form factor, $\int_0^\delta e^{-2\alpha}d(y/\delta)$, is found to be 0.396.

By Eq. (10), $\tau_0 = 2qD(\partial\delta/\partial x)$, and by Eq. (11), diss./sec./unit area $= qUE(\partial\delta/\partial x)$. One has then, for force and energy equilibrium,

$$0.664\,qR_x^{-1/2} = 2qD(\partial\delta/\partial x)$$

$$(0.396)(7.84)q(\nu/\delta) = qUE(\partial\delta/\partial x)$$

which integrate, respectively, to, $R_x^{1/2}(\delta/x) = 6.26$ for force equilibrium, and, $R_x^{1/2}(\delta/x) = 4.38$, for energy equilibrium. Directly from the treatment, a third value is found, namely, 5.20, or thereabouts, depending upon the integration, which is about the mean of the other two.

If the assumption of similitude were correct, all three values should of course, agree. It was the discovery of this disagreement, about four years ago, that initiated these minimum studies.

able except for a negligible spread near the outer limit of the layer.

(8) Finally, as noted previously, the minimum theorem analysis gives a new physical understanding both of transition and of turbulence, which is being used in further studies in this field.

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Book Review

The Chosen Instrument, by NORMAN MACMILLAN; John Lane, The Boadley Head, Ltd., London, 1938; 168 pages, 5s.

There are few writers on aeronautics who have the breadth of vision, clarity of expression, and knowledge of air power that Captain Norman Macmillan has shown in his writings. By profession a newspaper correspondent, he knows how to present views of world wide import in a succinct and convincing style. In his latest book he gives a frank and non-political picture of the present air status of the great powers with particular emphasis on the influence geographical positions will have on air strategy of the future.

Every military, naval, and air expert will find the broad problems that will confront each leading country in the event of war set forth from the point of view of an experienced student of world conditions. While the book covers a wide field in comparatively few pages, there is no evading of unpleasant issues by omission, but through condensation of presentation the author drives home point on point so quickly that his warnings of the danger of air power requires no reiteration.

The earlier chapters of the book contain a summary of the present state of aircraft development which, while familiar to those who read current aircraft periodicals, provide the uninitiated with background for the geographical considerations which follow.

While the book is primarily written to acquaint the British public with the changed position the British Empire occupies now that the potential power of aircraft is coming to be realized, it gives such a clear analysis of the air strength and weakness of the leading air powers that it is equally interesting and startling to forward looking readers of all countries.

Outspoken discussion of the comparative air strengths of France, Germany, Italy, Japan, Russia, and the United States bring the reader up to date with a shocking realization of the effects that aircraft operating over land and sea will have on the world's international relationships.

The United States, Captain Macmillan believes, is immune from attack, but he makes the interesting observation that the "air strength of the United States is like a weight which has not yet been placed in the scales balancing the remaining six air powers. Its weight might readily tip the scales either way. And because the people of the United States are safe from the risks that European peoples run in the event of an aerial war, America, as a powerful nation, could sway the issue with a decision which might indeed be remarkable."

In the chapter on Great Britain there is an argument that should be better understood by those who are decrying the use of aircraft against the civil population. After pointing out that the airplane, the machine gun, artillery, submarines, and battleships are merely the means of launching projectiles by means of high explosives or gravity, the author accounts for the present resentment against aircraft on the presumption that the public assume that soldiers and sailors do not really mind being killed in war. Their chances of a violent death are a part of their avocation. But the civilian is different. He has non-combatant rights that are not to be involved in warfare. "The aeroplane has upset the comfortable theory that the professional sailor and soldier are paid to be killed so that their brothers and sisters can live in peace. . . . If war had not been so coldly professional, if the politicians, the lawyers, and the merchants had had to take the front line instead of issuing decrees . . . there would be less of this craven fear of the aeroplane, and there would be far less risk of war stalking the world once more. But now politician, lawyer, merchant, their wives and children are all on the same footing as the soldier, sailor, and airman. In fact, their footing is not as good, for they have not the means to hit back."

Another interesting point is made against the generally accepted idea that ground forces will always be the determining factor in all conflicts. Until after the Armistice was signed in the Great War not a single allied soldier had set foot on German territory. German power of resistance was broken without the need for invasion. Thus, the author holds, it cannot be held that infantry must occupy territory of a country to force it into signing an Armistice.

LESTER D. GARDNER

Some Problems in the Design of High-Speed Aircraft

LLOYD H. LEONARD, *National Advisory Committee for Aeronautics*

Presented at the Air Transport Session, Sixth Annual Meeting, I. Ae. S.
January 27, 1938

SUMMARY

An analysis of important technical problems in the design of high-speed aircraft is presented. The results are illustrated by graphs that show the comparative effectiveness of different methods of increasing flying speed. High wing loading is revealed to be the greatest need for higher speeds at sea level. The optimum wing loading for maximum flying speed is shown to be that required to fly at the maximum L/D of the wing and tail surfaces. The increase in the optimum wing loading with flying speed at sea level and its variation with altitude are graphically illustrated. At 400 m.p.h. the optimum wing loading is shown to be of the order of 300 lbs. per sq.ft. at sea level but it is only 25 lbs. per sq.ft. at 60,000 ft. altitude. Design alterations permitting higher wing loadings than are now in use are recommended.

INTRODUCTION

THE trend in aeronautical design is toward increased speed. Although both commercial and military airplanes of modern design are about twice as fast as those in common use only a few years ago, the quest for speed is more in evidence than ever before. It seems probable that the trend toward higher speeds will continue in the future. Speed is becoming an increasingly important requirement in design.

In an era of such rapid development, technical considerations are of vital interest. Unfortunately, it becomes more difficult to achieve a given increase in flying speed as higher speeds are attained. Design variables that require only moderate consideration at low speeds may become vitally important at high speeds.

This paper is concerned primarily with those variables in design that have a large effect on the flying speed.[1] Variables considered to be of secondary importance are eliminated by making simplifying assumptions.

DRAG EVALUATION

In this analysis the total drag of an airplane in steady horizontal flight is divided into wing drag, tail drag, and parasite drag. Contrary to usual practice, the parasite drag, as used in this paper, includes all of the drag excepting that of the wing and tail. The wing and the vertical and horizontal tail surfaces are grouped together as a unit by assuming the total tail area to be 25 percent of the wing area. As a further approximation a drag coefficient C_D of 0.009 and a propulsive efficiency of 80 per cent are selected.

The foregoing selected value of C_D exceeds the average drag coefficient for smooth wind-tunnel models at low angles of attack and high Reynolds Number by a sufficient amount to allow for slight surface irregularities which are unavoidable in actual construction. The effect of changes in Reynolds Number is disregarded because, in practical design, very high Reynolds Number is likely to be associated with high flying speeds, at which the increase in the drag coefficient due to compressibility tends to compensate for the decrease resulting from the higher Reynolds Number. Actual measurements for a wing of 5 ft. chord show that the drag coefficient begins a gradual increase at about 250 m.p.h. The foregoing drag coefficient is selected to represent a fair average value for the range of flight conditions with which this paper is concerned.

Upon the basis of these assumptions there results the following equation

$$C_{DP}S_P/P = [370{,}000/(\rho V^3/\rho_0)] - 0.01125\, S_W/P \quad (1)$$

in which C_{DP} is the parasite drag coefficient based on the parasite frontal area S_P, S_W is the wing area, P is the engine horsepower, ρ/ρ_0 is the air density ratio, and V is the flying speed in ft. per sec.

In Eq. (1) the term S_W/P indicates the number of sq.ft. of wing area per horsepower and is equal to the power loading divided by the wing loading. The term $C_{DP}S_P/P$, which in this analysis is called the "parasite factor," represents, at a given parasite drag coefficient, the number of sq.ft. of parasite frontal area per horsepower.

PERFORMANCE GRAPHS

The variation of the parasite factor with flying speed at sea level is graphically illustrated in Fig. 1. The value $S_W/P = 5$, which represents very lightly loaded, low-powered airplanes, is about the maximum used in airplane design. The shaded portion of Fig. 1 represents, approximately, the practical limiting range of operation of actual airplanes.

The performance of any airplane may be indicated in Fig. 1 by a point. The points that represent the performance of light airplanes lie in the neighborhood of circle A; those for airplanes of moderate speed lie near circle B; those for high-speed transport airplanes lie

[1] After the completion of this paper, the author's attention was called to a similar analysis by H. F. Vessey, *The Effect of Wing Loading on the Design of Modern Aircraft*, with particular regard to the take-off problem, lecture delivered before the Royal Aeronautical Society in London, Nov. 18, 1937.

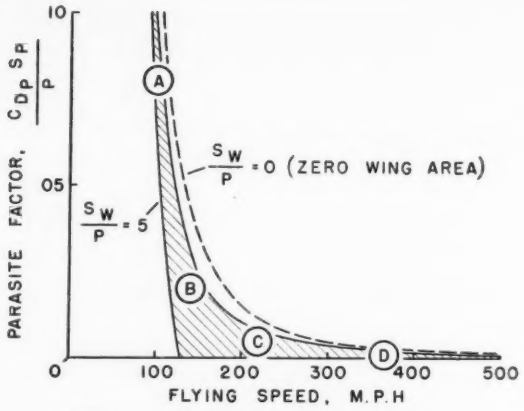

FIG. 1. Performance graph for all speeds.

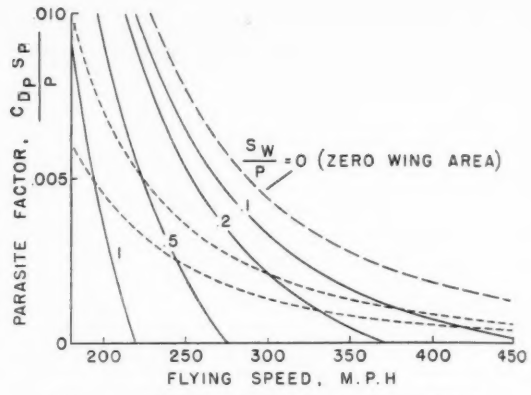

FIG. 2. Performance graph for high-speed range.

near circle C; and those for very fast military aircraft and special racing airplanes lie near circle D.

USE OF THE GRAPHS

In Fig. 2 the high-speed portion of Fig. 1 is plotted to a larger scale. Starting at any point representing the performance of a specific airplane (which point may be determined for an existing airplane if the value of S_W/P and the corresponding flying speed are known), a change in wing loading is represented by a horizontal movement on the graph. The increase or decrease in wing loading is directly proportional to the accompanying change in the value of S_W/P. The scale at the bottom of the graph shows the corresponding variation in the flying speed. The absolute limit in speed, hypothetically attainable by reducing the wing area to zero, is indicated by the point of intersection with the curve for $S_W/P = 0$.

A change in parasite drag, whether it be realized by varying the parasite frontal area or the parasite drag coefficient, is illustrated in Fig. 2 by a movement in the direction indicated by the curved lines of constant S_W/P. The magnitude of the change in parasite drag is represented by the corresponding change in the value of the parasite factor. The resulting variation in flying speed is easily read on the scale at the bottom of the graph. The speed attainable by reducing the parasite drag to zero, a condition approached in the so-called "flying wing," is shown by the point of intersection of the path of constant S_W/P with the bottom horizontal line of the graph.

A variation in horsepower is represented by a movement along a path extending from the original point along the dotted lines of Fig. 2. The change in horsepower is inversely proportional to the accompanying change in the value of the parasite factor.

Fig. 2 is useful, primarily, for comparing different methods of increasing flying speed. Such comparisons are valuable as an indication of the changes in design which are likely to be most effective in increasing the flying speed of any specific airplane. The resultant effect of altering more than one variable by any desired amount may also be estimated.

PARASITE DRAG COEFFICIENT

The reduction in the parasite factor of any airplane that may be realized by improved streamlining depends on the cleanness of the design. An analysis of several relatively clean modern monoplanes indicates that their parasite drag coefficients may be reduced to a minimum of about 60 percent of their present values by refinements in design. The increase in flying speed attainable by such a reduction may be estimated for any given airplane by use of Fig. 2.

OPTIMUM WING LOADING

At the high lift coefficients associated with increased wing loading the induced drag becomes large. Taking into account variations in the induced drag, the parasite factor may be expressed by the equation

$$\frac{C_{D_P} S_P}{P} = \frac{370{,}000}{\rho V^3/\rho_0} - \left[\frac{C_{D_0} + 0.00225}{C_L} + \frac{C_L}{\pi A}\right] \frac{841\ (W/P)}{\rho V^2/\rho_0} \qquad (2)$$

in which C_{D_0} and C_L are the profile-drag and lift coefficients of the wing, respectively, A is the aspect ratio, and W/P is the power loading in lbs. per hp. The expression within the brackets represents the D/L of the wing and tail surfaces as a unit. Accordingly, Eq. (2) becomes

$$\frac{C_{D_P} S_P}{P} = \frac{370{,}000}{\rho V^3/\rho_0} - \left(\frac{D}{L}\right)_{W+T} \frac{841\ (W/P)}{\rho V^2/\rho_0} \qquad (3)$$

It may be shown that, as the flying speed is increased, $(D/L)_{W+T}$ must decrease, if the other variables are assumed constant. For a given aspect ratio, therefore, the maximum flying speed that may be realized by varying the wing loading occurs at the lift coefficient for which the value of $(D/L)_{W+T}$ is a minimum. For any airplane, the wing loading required to fly at this

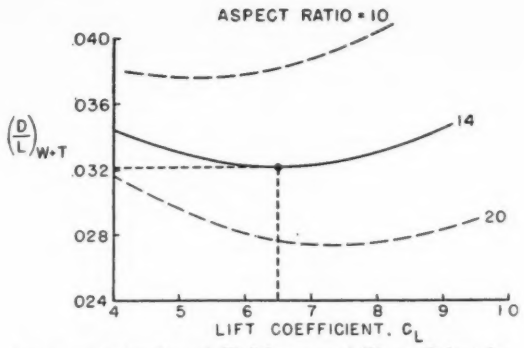

FIG. 3. Evaluation of $(D/L)_{W+T}$ and lift coefficient for optimum wing loading.

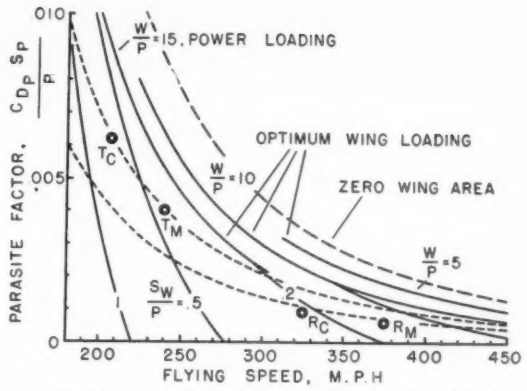

FIG. 4. Performance graph with optimum wing loading curves.

lift coefficient may be called the "optimum wing loading."

In Fig. 3, $(D/L)_{W+T}$ is plotted as a function of the lift coefficient for three aspect ratios, based on data for the N.A.C.A. 23012 airfoil at an effective Reynolds Number of 8,160,000. The minimum value of $(D/L)_{W+T}$ decreases as the aspect ratio is increased. Accordingly, it is desirable that the aspect ratio be as high as possible. In this analysis the optimum wing loading is estimated for an aspect ratio of 14, although even higher aspect ratios may be structurally permissible. According to Fig. 3 the minimum value of $(D/L)_{W+T}$ for an aspect ratio of 14 is 0.0321, at which value the lift coefficient is $C_L = 0.65$.

Substituting $(D/L)_{W+T} = 0.0321$ in Eq. (3) the parasite factor for the optimum wing loading becomes

$$\frac{C_{D_P} S_P}{P} = \frac{370{,}000}{\rho V^3/\rho_0} - \frac{27\ (W/P)}{\rho V/\rho_0} \qquad (4)$$

Fig. 4 shows three curves representing the optimum wing loading at sea level, as determined by Eq. (4). At the power loadings specified, these curves indicate, approximately, the maximum sea-level flying speed that may be realized at any given parasite factor by varying the wing loading.

An Analysis of Typical Airplanes

The points T_M and T_C in Fig. 4 represent a typical modern transport airplane at maximum flying speed and at cruising speed, respectively. A wing loading of 25 lbs. per sq.ft., a power loading of 10 lbs. per hp., and a maximum flying speed of 240 m.p.h. are assumed. Similarly the points R_C and R_M represent a typical modern racing airplane having a wing loading of 35 lbs. per sq.ft., a power loading of 5 lbs. per hp., and a maximum flying speed of 375 m.p.h. In each case, the power at cruising speed is assumed to be 65 percent of that at maximum speed.

In the case of the transport airplane at maximum speed, represented in Fig. 4 by the point T_M, the speed may be increased from 240 to 274 m.p.h. by increasing the wing loading to the optimum value. Roughly 295 m.p.h. could be realized by eliminating the parasite drag entirely at the original wing loading. Assuming that the parasite drag were reduced to 60 percent of its original value the speed would be increased to about 258 m.p.h. If the parasite drag were reduced to 60 percent and the wing loading were then increased to the optimum value, a maximum speed of 318 m.p.h. would be realized. It is to be noted that all of the above-mentioned increases in speed assume no increase in horsepower. At twice the original power the speed according to Fig. 4 would be 303 m.p.h., which is less than the maximum attainable by the combination of improved streamlining and increased wing loading.

Advantages of High Wing Loading

A similar analysis for each of the points representing the typical airplanes in Fig. 4 reveals that the increase in speed attainable by reducing the parasite drag changes only slightly; whereas the increase that may be realized by increasing the wing loading becomes materially greater as the flying speed is increased. For example, in the case of the racing airplane at cruising speed, represented in Fig. 4 by the point R_C, an increase in cruising speed at sea level from 325 to only about 355 m.p.h. is possible even if the parasite drag is entirely eliminated; but, by increasing the wing loading to its optimum value, estimated for the cruising power loading of $W/P = 7.7$, a cruising speed in the neighborhood of 425 m.p.h. may be realized. Increased wing loading, therefore, is more important than improved streamlining as a means of increasing the flying speed of high-speed airplanes at sea level.

Optimum Wing Loading at Sea Level

In Fig. 5 the optimum wing loading at sea level is plotted as a function of flying speed for aspect ratios of 10, 14, and 20. The required wing loading increases with both aspect ratio and flying speed and it is extremely high at very high speeds. For example, at an aspect ratio of 14, a speed of 250 m.p.h. requires an optimum wing loading of slightly more than 100 lbs. per

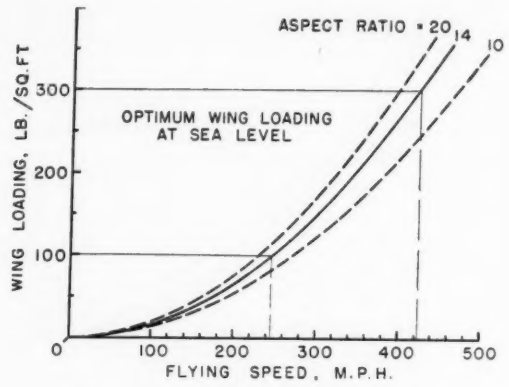

FIG. 5. Optimum wing loading at sea level.

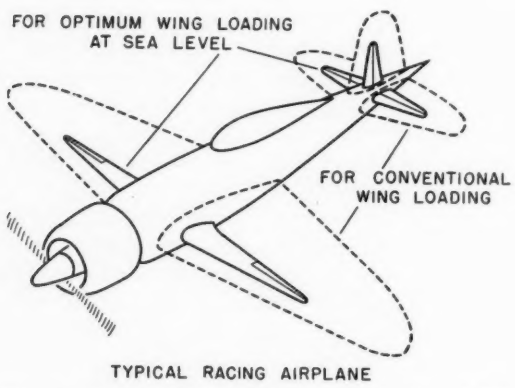

FIG. 6. Airplane having optimum wing loading of 300 lbs. per sq.ft.

sq.ft., while a loading of 300 lbs. per sq.ft. is needed at a speed of 425 m.p.h.

As an illustration of the extraordinarily small size of the wing and tail surfaces resulting from the use of such high wing loadings, a hypothetical racing airplane having wing and tail surfaces designed for an optimum wing loading of about 300 lbs. per sq.ft. is shown in Fig. 6. Wing and tail surfaces of normal proportions, as required by present-day take-off and landing requirements, are shown dotted for comparison.

VARIATIONS OF THE OPTIMUM WING LOADING WITH ALTITUDE

As the altitude of flight is increased the optimum wing loading, at a given flying speed, decreases due to the reduction in air density. At very high altitudes it is well within the limitations established by present-day take-off and landing requirements. Flight at the optimum wing loading even at very high speeds is possible, therefore, without excessive wing loading provided that the altitude is sufficiently high. The increase in flying speed with altitude for several optimum wing loadings at an aspect ratio of 14 is shown in Fig. 7. Assuming a wing loading of 25 lbs. per sq.ft., a flying speed of 250 m.p.h. requires an altitude of 40,000 ft., while at 60,000

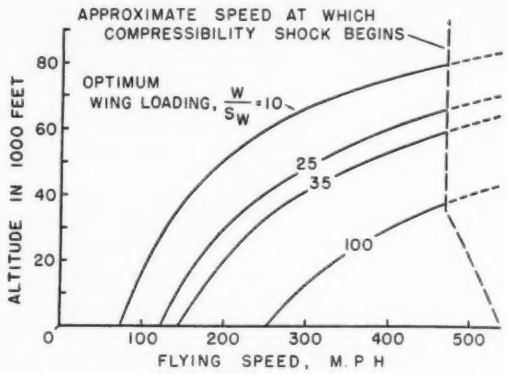

FIG. 7. Variation of optimum wing loading with altitude and flying speed.

ft. a speed of 400 m.p.h. is permissible. If the wing loading could be increased to 100 lbs. per sq.ft., however, a speed of 400 m.p.h. would be permissible at only 30,000 ft. altitude.

THE FLYING WING

The light optimum wing loading required at high altitudes is favorable to the use of transports of the flying-wing type in the upper stratosphere. At lower altitudes the higher optimum wing loading results in a smaller wing size for a given gross weight; hence, the flying wing is less practical. Near sea level transports of the flying-wing type are entirely impractical if flight at the optimum wing loading is to be maintained, unless the flying speed is very low or the gross weight is extraordinarily high.

COMPRESSIBILITY

The dashed line of Fig. 7 indicates the estimated limit in flying speed as determined by the compressibility shock. It is to be noted that the limit, which is of the order of 540 m.p.h. at sea level, decreases to about 470 m.p.h. at 35,000 ft. and is constant for higher altitudes. Flying speeds above about 470 m.p.h., therefore, are possible only at low altitudes unless the adverse effects of the compressibility shocks can be eliminated.

POSSIBILITIES OF REALIZING THE OPTIMUM WING LOADING

It is advantageous to fly at the optimum wing loading when speed is an important consideration. To do so at high velocities, however, requires either that the altitude of flight be high or that the wing loading exceed present-day values.

Flight at high altitudes requires special superchargers and pressure cabins and introduces other complications in design. Moreover, because of the time required during ascent and descent, high-altitude flight is practicable only on long trips. Also, as has been shown, compressibility limitations favor low altitudes at extremely high speeds. The main advantage of high-altitude flight is that it makes possible a realization of the optimum wing

loading at high velocities. At best, however, it is not an entirely satisfactory solution of this problem.

The only other alternative is high wing loading. Although it is beyond the scope of this paper to consider in detail methods by which wing loading in excess of present-day values may be used successfully in practical design, a few considerations are worthy of mention. An ideal solution of the wing loading problem would be to devise a practical method of taking off and landing entirely independently of the wing. Any desired wing loading could then be used. In conventional airplane design, improvements in lift-augmenting devices, the use of catapults as aids during take-off, and refinements in landing gears to reduce the shock of landing and to permit more effective braking are suggested. Although even the combined effect of these and other improvements may not permit wing loadings as high as 300 lbs. per sq.ft., loadings much above present values appear to be attainable. The problem of realizing higher wing loadings is worthy of consideration and study since its solution will make possible a substantial improvement in the high-speed performance of airplanes.

Conclusions

(1) Increased wing loading is more important than improved streamlining as a means of increasing the flying speed of modern high-speed airplanes at sea level.

(2) The optimum wing loading for maximum flying speed is that required to fly at the maximum L/D of the wing and tail surfaces.

(3) The optimum wing loading increases with flying speed at a given altitude and decreases with altitude at a given flying speed.

(4) At flying speeds above 400 m.p.h. at sea level the optimum wing loading is of the order of 300 lbs. per sq.ft.

(5) At an altitude of 60,000 ft., the optimum wing loading is only 25 lbs. per sq.ft. at 400 m.p.h.

(6) Changes in airplane design and operation to permit higher wing loadings are worth consideration.

Book Review

Over the North Pole, by George Baidukov; Harcourt, Brace & Company, New York, 1938; 99 pages, $1.50.

If a ghost writer with a flair for dramatizing incidents which, while routine, might have serious consequences, had written an imaginative account of a flight over the North Pole he could not have done better than Baidukov. Unfortunately, when the Soviet pilots were entertained at dinner in New York he was sick and could not speak. The Soviet Ambassador, A. A. Troyanovsky, in introducing the other two pilots of the flight, Chkalov and Beliakov, said that Baidukov is the son of a worker in Soviet railroad yards and is a typical product of the Soviet ideology. Under "the previous regime he would have stifled in some insignificant dull life in a remote corner of Russia." Now he holds the highest of Soviet honors, being one of the "Heroes of the Soviet Union."

Vilhjalmur Stefansson in his preface epigramatically writes that on a monument built to them might well be engraved "They found the world of transportation a cylinder; they left it a sphere." He prophesies that "there seems to be no reason why, in case of a national emergency such as, for instance, a war in the Pacific, it would not be possible to send 24,000,000 tons around the north coast of Asia next year by the same process that took the 24,000 tons through that passage last year."

Not the least interesting part of the book are the earlier chapters which give an intimate account of the personal interest and instructions that Stalin and the leaders of the Soviet Union gave to the preparations and conduct of the flight. It is refreshing to read of a flight that was made solely for national prestige without any commercial aspects, or having to put a halo of contributions to science on the achievement. The book is another document of evidence of the interest that is being taken in aviation in high places in modern Russia.

The account of the flight is so well written and keeps the reader's interest so sustained that the book will be read to the end by almost anyone without stopping. The emphasis on the fatigue of the pilots is somewhat overdone but more is becoming known of the physiological effects of continuous flight at ten to twenty thousand feet. The three pilots flew 5507 miles from Moscow to Portland, Oregon, in somewhat over sixty hours. Instead of criticizing the author for picturing the results of oxygen want so vividly, we may eventually come to believe that this description may be the greatest contribution this flight made to the advance of aviation.

Certain anomalies appear when flying over the Pole and Baidukov uses them to make the account of the flight more interesting. One minute they were flying North along the 58th meridian and the next minute they were flying South along the 123d meridian without changing their course. While their clocks, which were on Greenwich true time, showed 4:42 p.m., they knew it was already night in Moscow and it was morning at Portland. They knew that at that time of the year there is twenty-four hours of daylight at the Pole. Owing to the location of the magnetic pole not being at the North Pole, their magnetic compasses told them a different story than their sun compass. If they looked ahead or behind they were looking South. If Baidukov called to the pilot from the cabin he might be speaking at noon and his message heard at midnight. Such are some of the queer contradictions that occur where the axis of the earth emerges from the sphere.

For the sake of historical accuracy it might be pointed out that the book's closing paragraphs give a rather different impression of the end of the flight than the description given by the pilots on landing on June 22. The book says they were out of gas, but on landing Chkalov denied that the fuel pump had been out of order and said that they had gas to continue 750 miles farther. No mention is made of the original destination of the flight, Oakland, California, where the Soviet Ambassador was waiting. On landing it was said that Chkalov was at the controls during the entire flight, whereas the book describes him as giving the controls to Baidukov whenever blind flying was required and that Baidukov flew the last ten hours, and landed the ANT 25 at Portland while Chkalov was "cleaning up, disposing of strings, used papers, and stowing away maps and notebooks." These minor differences are understandable as the pilots knew no English and the book was written from the log and not by interviews.

The flight may truly be termed "epic" as it was well planned, perfectly executed, and accomplished the objective of establishing what will be known as the Stalin Route which extends from the United States over the Pole to the Siberian section of Russia.

Lester D. Gardner

Performance and Control of Rotary-Wing Aircraft

E. BURKE WILFORD, *Pennsylvania Aircraft Syndicate*

Presented at the Rotary Wing and Lighter-than-Air Aircraft Session, Sixth Annual Meeting, I. Ae. S. January 25, 1938

THE rotorplane field today is in the same scientific position as flaps were at the time of the Guggenheim contest. Enough experiments have been successfully completed to show that the utility of the basic system is established. Up to the present time the advantages of rotary-wing aircraft over fixed-wing aircraft have been their inability to stall and spin and their large speed differential.

In order to realize the full usefulness of these advantages, it is necessary to think of the gyro in general, not simply as an improved airplane but as a new method of getting about in the air. It does not compete with the airplane in stunting, speeding, or fast climbing to high ceilings; yet it can perform many tasks better than the airplane and can undertake many others which the airplane cannot attempt. Rotary-wing aircraft cannot easily do loops and rolls and few can do vertical flipper turns; yet they can turn a shorter radius when banked 30° than an airplane can in an 80° bank.

Their climb is more modest in ft. per min., but they can outclimb an airplane in ft. per mile and this is what counts to a great many flyers. Ordinarily, steepness of climb means much more than rate of climb for the majority of uses to which an air vehicle may be put.

Up to the present time rotary-wing aircraft have been designed for landing with little or no forward speed. This has been done partly because of the desire for safety of experimental flying and partly because of the sensational effect of vertical descent on the public mind. As a result, the higher speed type of gyro has received little attention, notwithstanding the fact that the speed differential of rotary-wing aircraft is greater than it is for the fixed-wing type. However, as soon as a definite amount of landing velocity is assigned to a gyro, its high speed can be materially increased. The most practical and safest landing speed is about 30 to 40 m.p.h. considering the various velocities of wind.

Landing Speed

The tendency of fixed-wing design has been to increase performance, with a comparative increase in landing speed by reducing the parasite drag and wing area and increasing the horsepower. Requirements of aircraft transportation demand higher speed with the consequent result that landing speeds are becoming almost too fast for the present type of good fields and entirely too high for emergency landings.

Such devices as the Curtiss Slot and Flap, the Zap Trailing Edge Flap, the Fowler Variable Area Wing and other radical wings are being used for this purpose. These devices have reduced the landing speed from 90 m.p.h. to 60 m.p.h., but for speeds under 50 m.p.h. these devices will not suffice.

Take-off of these large transports and seaplanes has become so long that mechanical assistance during take-off is a crying necessity, particularly for reasonable pay load in long range flight.

The best gyro today has a minimum velocity for constant altitude of approximately 25 m.p.h., and a top speed of 125 m.p.h., and hence a speed range of about 5. If a minimum flying speed for constant altitude of 40 m.p.h. is assigned, and a speed range of 5 is maintained, a top speed of 200 m.p.h. will be the result. This will not allow vertical descent but will permit landings on very limited areas, as well as make safe and easy almost any emergency landing. To get out of the area in which a gyroplane has landed, quick take-off is essential. The work on this subject seems to indicate that machines loaded at less than 2 lbs. per sq.ft. of disc area can efficiently make standing take-offs.

Fixed-wing aircraft, during a period in their early development corresponding to the present development of the gyro, did not attain a speed differential even as high as 2. At the present time with all the best known means of reducing landing speed, fixed-wing aircraft cannot possibly be expected to have a speed range much over $3^1/_2$ and this has been achieved after years of intensive engineering and development. On the other hand, rotary-wing aircraft in their present early stage of development have already attained a speed range of 5, and it is only reasonable to assume that with refinement in engineering this speed range can be increased at least to 6 and perhaps more. It seems logical, therefore, that rotary-wing aircraft can more easily increase their *high* speed than fixed-wing aircraft can reduce their *landing* speed.

The various types of rotary-wing aircraft, which have been successful are the following: The hinged blade type known commercially as the Autogiro, the rigid feathering rotor type known as the Gyroplane, and the Vertaplane consisting of a two bladed rigid rotor pinned

to the hub, all of which according to the dictionary are gyroplanes.

The Autogiro

The Autogiro, as developed in this country and England, has a rotor the blades of which are hinged to the hub so that as they rotate they rise and fall, thereby changing the effective angle of incidence to compensate for difference in velocity and lift between the advancing and retreating blades.

The Autogiro during the past few years has undergone an experimental overhaul. The rotor is directly controlled by tilting the axis, no fixed wing and no rotating cables to cause drag. The L/D is greater than before; top speeds are higher, minimum speeds with power are lower. A speed range of 5 has been accomplished. In one of the latest forms, this type is built so that the blades can be folded back and a drive to the rear wheel allows for running along the roadway.

The Gyroplane

The feathering Gyroplane was conceived in Germany and was developed and flown in this country. It consists of a rigid rotor in which the blades change their angles during the course of each revolution so as to compensate for the difference in velocity or lift between advancing and retreating blades. This was accomplished first by aerodynamic feathering and later by mechanical feathering. In the early experiments the opposite blades were inner-connected and had sweepback, so that the lifts of opposite blades were balanced against each other. The control for the airplane was provided by the normal ailerons and tail surfaces.

This was improved in 1931 and 1932 by the addition of a control mechanism which mechanically feathered the blades in proportion to the position of the control stick so that rolling or pitching moments could be imposed on the rotor disc at the will of the pilot. This made extended flights possible and gave ample control for ordinary flying maneuvers.

Early flight tests showed that the control at low speed was just as effective as at high speed. Since the rotor speed is nearly constant, the degree of control is equally powerful throughout the entire speed range. Stunting in airplanes grew from the large excess of control which the airplane has at its higher speeds. Control surface areas which were designed to give sufficient control at low speeds give 6 to 9 times too much control at high speeds. If Gyroplanes had a control powerful enough for stunting they would require heavier structures than are necessary for ordinary maneuvers of straight flying, hence with normal control the load factors of gyros need not be as great as in fixed-wing aircraft.

Gyroplanes can be designed with fixed wing or without, depending on the type of service and performance required. When the rotor alone is used a lower L/D results, but the saving of the wing weight allows steeper take-off and descent.

The rigid feathering system lends itself to high disc loadings. Loaded from 2.5 to 4 lbs. per sq.ft., it will not land vertically but can land so steeply that little advantage is lost. However, its high-speed performance should be comparatively good for two reasons. First, the rotor is smaller and turns faster and its drag is less on account of its small size. Secondly, it flies flat or almost flat and the projected area, being so small, reduces the profile drag to a small amount.

Contrary to popular belief, the lift of the blade is not all taken by bending; only about half of it is carried by bending stresses and the other half is taken by the deflection of the blades times the centrifugal force, which is augmented by this faster turning speed. Blades for the Gyroplane must be designed stiff enough so that they will not hit the tail in taxiing and this condition frequently requires as much material as the flying condition. Therefore, the blade weights for Autogiros and Gyroplanes of the same size are almost identical.

One could go on indefinitely regarding structural details of rotary-wing aircraft, but the scope of this article obliges the author to confine himself to (1) a combination of fixed wing and rotor, and (2) stopping the rotor in flight, as methods for increasing performance while still maintaining reasonable landing speeds.

Combination of Fixed Wing and Rotor

The proper use of a wing on a Gyroplane of the rigid feathering system can markedly increase its performance. This is particularly true of high speed and climb because of the improvement in L/D.

When a rotor is flown at a low angle and the lift load is mostly taken by the wing, its drag falls off sharply. In the best combination of wing and rotor, the wing has only area enough to lift about the weight of the ship at cruising speed when the wing is flying at its angle of maximum L/D. At high speed the rotor is unloaded and has slowed down its revolutions considerably. It is then kept going by difference of drag and not by autorotation. Its lift is low and it is flying near its minimum drag. With this combination the net L/D of the total lifting surface would be in the neighborhood of 17. This makes the high speed and climb quite comparable to that of the airplane, while the slow landing speeds and steepness of descent and ascent are far superior.

This method of using a wing is only applicable to the rigid feathering rotor system, the Gyroplane. Due to the rigid blades the slowing down of the rotor does not change the position of the blades, and when the load is applied by increasing the incidence, the blades pick up rotary speed quickly. It is logical that in this type of Gyroplane the rotor be loaded rather heavily, say from 2 to 5 lbs. per sq.ft. This will require definite landing speeds of from 30 to 40 m.p.h., but the steep angle of

glide and powerful rotor control at high and low speeds will permit easy landings in limited areas.

In order to make clear the advantage of using a rotating wing in combination with a fixed wing the performance was calculated for four aircraft all having the same gross weight of 3400 lbs., and the same horsepower (420), as follows:

(1) Modern efficient fixed-wing airplane. Low wing monoplane of monocoupe metal construction, similar to the Curtiss 19-R, with a wing area of 174 sq.ft.

(2) The same airplane as in (1) but without wing and with a rotor 1134 sq.ft. in area.

(3) The same as (2) but with the addition of a wing having an area of 154 sq.ft., the rotor being unloaded and allowed to idle in the high-speed condition.

(4) The same as (3), but having the rotor stopped in the high-speed condition. (Similar to the recent convertible aircraft which Gerard P. Herrick has so successfully demonstrated.)

Curves of power required and power available were calculated from data published by the N.A.C.A. in Technical Report No. 536 and other reports. The fixed wing when used with the rotor was set at a positive decalage angle to the rotor disc of about two or three degrees so that at cruising speed the wing assumed the total load and the rotor was in a no-lift attitude.

The results are given in Table 1 in which the landing velocity is divided into its vertical and horizontal components. The 20° attitude for this gyroplane gives a vertical landing velocity closely comparable to that of the airplane, but the horizontal components are much less. The speed ranges are based on these horizontal components at 20° attitude.

TABLE 1

Table of Speeds, m.p.h.

Gross Weight—3400 lbs. Horsepower—420

Type	Useful Load, lbs.	High Speeds	Landing Speed Components Vertical	Landing Speed Components Horizontal	Speed Range of Horizontal Velocity
(1) Airplane	1420	206.2	10.9	60.3	3.42
(2) Wingless Gyroplane	1290	148.6	11.62	32.0	4.64
(3) Gyroplane, Rotor Unloaded	990	176	10.81	29.7	5.92
(4) Gyroplane, Rotor Stopped	990	199.8	10.81	29.7	6.72

Book Reviews

Australia Advances, by DAVID M. DOW; Funk & Wagnalls Company, New York and London, 1938; 268 pages, $2.00.

Normally this book would not be reviewed in the Journal. But for special reasons one of its chapters deserves comment.

If anyone were to ask what country had produced the most famous aviators the answer would obviously include the four or five largest countries, but when the list is examined further it will be found that Australia ranks with the others.

The genial representative in New York of the land of the Southern Cross has given a full chapter to the aeronautical record of Australia. Starting with Hargrave whose place as an early experimenter will always have high rank, he gives short accounts of the flights of Harry G. Hawker, Sir Ross and Keith Smith, Hinkler, Gatty, Taylor, Ulm, Kingsford-Smith, and Sir Hubert Wilkins. But in addition to the feats of this list of great pilots, Australia is famous in aeronautical circles for its aerial medical and nursing services. No matter in what part of Australia sickness occurs, a telephone or radio message brings a physician or a nurse. And when one sees the map of the continent "down under" superimposed on that of the United States, a more correct impression is secured as to the need for such a humane service.

Mr. Dow has rendered a genuine service to his country by preparing such an interesting volume. Those who refer to it to read the aeronautical chapter will be greatly interested in the other chapters as well.

Air Rule of the Road, by LIEUT.-COMMANDER R. SUNNUCKS; Brown, Son & Ferguson, Ltd., Glasgow, Scotland, 1937; 79 pages, ill., 5s.

This book is a compilation of definitions and legal navigational requirements for prospective candidates for an English Second Class Air Navigator's License. While it will undoubtedly prove a useful text book for novices it will be of little value to American pilots other than to acquaint them with the English rules of the air. The final chapters of the book show in color the requirements for aircraft and vessels for displaying lights and signals, the insignia of military aircraft and sketches of the leading types of European aircraft. While it will be useful for a text book, rules for air navigation change so rapidly that it will soon lose its usefulness for American pilots who contemplate flying in the United Kingdom.

Ground Effect with Special Reference to Pitching Moments

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Presented at the Aerodynamics Session, Sixth Annual Meeting, I. Ae. S.
January 26, 1938

I. Introduction

A FACTOR which plays an important role in the design of the horizontal tail surfaces of an airplane is the effect of the ground upon the pitching moment in the landing condition. An airplane capable of being trimmed at all attitudes in the air often cannot be landed in the three-point position because of insufficient elevator control near the ground.

In an attempt to obtain quantitative measurements of this phenomenon, and to investigate the adequacy of control of certain proposed airplane designs, the experiments described herein were performed in the ten-foot wind tunnel of the GALCIT.[1] In these tests the ground was represented by a smooth flat plate fixed in the tunnel. It is believed that this method of representing the ground, although not exact because of the presence of the boundary layer on the plate,[2] is sufficiently precise to give value to the results.

A considerable amount of experimental data regarding the effects of the ground plate upon lift and drag was obtained incidentally to these investigations. Some of these data are presented in Sections IV and V.

II. Description of Tests

The ground plate used in the wind tunnel is shown in Figs. 1 and 2, which also illustrate the method of model suspension employed. The leading edge of the plate was rounded, and the surface was smooth and polished. A survey of the velocities near the plate was made with a small pitot-static tube. The velocity was found to attain its free-stream value less than one inch from the plate at the wing position, and less than 1.5 in. from the plate in the tail position. The tail surfaces did not approach the plate this closely in any of the tests. In conjunction with some of the tests, particularly with flaps deflected, the airstream near the tail was probed with a piece of silk floss, and it was determined that no separation from the plate or other noticeable peculiarities were occurring in the flow.

The airplane models tested were supplied by various manufacturing companies, and were all models of existing or proposed commercial or military airplanes. All are "conventional" types, with two or four engines.

The tests were carried out at tunnel airspeeds of between 150 m.p.h. and 180 m.p.h. The corresponding Reynolds Numbers are given in Table 1, as are important model dimensions and data regarding the location of the ground plate relative to the model.

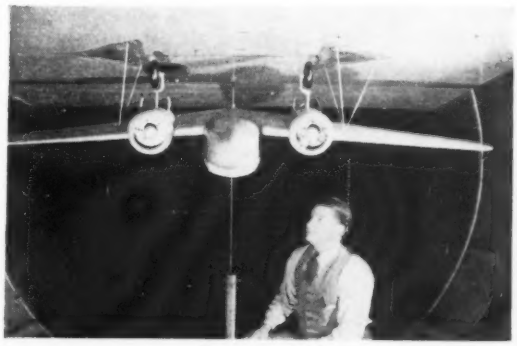


Fig. 1. Model and ground plate installed in wind tunnel.

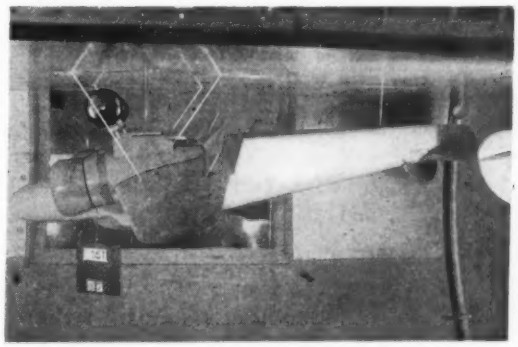


Fig. 2. Model and ground plate installed in wind tunnel.

III. Effect on Pitching Moments

The effects of the ground plate upon the pitching moments of the six models are shown in Figs. 3–11. The data, both with and without ground, have been corrected for wind-tunnel wall interference, by the usual methods for circular tunnels, since more accurate corrections for the tunnel with ground plate are not available. The correction is small in any case. The subscript on C_M indicates approximately the distance from the leading edge of the mean aerodynamic chord to the reference point for pitching moments, measured in percent of the chord.

The most important results obtained from Figs. 3–11 are the following:

(1) The primary effect of the ground upon the pitching moment curve for elevators neutral is an increase of slope ($-dC_M/dC_L$). The change in C_M at $C_L = 0$ is small in every case, and varies in sign.

(2) The elevator effectiveness, dC_M/de (where e = elevator deflection) is not greatly affected by the presence of the ground. When it is affected, it is increased slightly (probably due to un-stalling of the tail with elevators up) so that the assumption of no change would be conservative as regards trim in landing.

(3) The pitching moment curve for the tail-off configuration is practically unaffected by the ground. This means that result (1) is caused almost entirely by the effect of the ground upon the pitching moment due to tail surfaces.

It is easily seen that these results combine to shorten the range of forward center-of-gravity positions for which trim (*i.e.*, $C_M = 0$) is possible near maximum lift. That is, the ground increases the diving moment for elevators neutral near maximum lift, but does not consistently increase the stalling moment available from elevator deflections. Thus the net stalling moment available, to obtain trim in the three-point attitude with far-forw ardc.g. positions, is decreased by the presence of the ground.

The curves labeled "calculated" in Figs. 3 to 11 have been obtained by adding to the experimental "without ground" curves for elevators neutral an amount ΔC_{M_t}, which gives the calculated effect of the ground upon the pitching moment due to tail surfaces. The calculation has been made by replacing the ground by a stream surface using the well-known method of image vortices, and determining the net downwash at the tail position due to the wing and its image. The change in moment, ΔC_{M_t}, has then been calculated from the difference in net downwash with and without ground, as described in more detail in the Appendix. The calculated curves marked "B" have been obtained by the simplified method described therein, while those marked "A" (Figs. 3 and 4 only) are the results of a much more detailed calculation, which is also explained in the Appendix. It is apparent that the differences between the results of the two methods of calculation are small compared with the serious disagreement between them and the experimental results.[3] This disagreement seems to be smaller in the cases with flaps down, although the assumption of elliptic lift distribution, which is made in the theory, is surely questionable for these cases.

Similar calculated curves could be drawn for the elevator-deflected configurations, but have been omitted to prevent crowding the figures and because of the poor agreement with experiment. It appears that the present theory gives the designer only a rough estimate of the ground effect in those cases where wind-tunnel tests with the ground plate are not available. This estimate is, however, consistently conservative as regards allowable c.g. travel for trim in landing.

IV. Effect on Lift and Drag (below $C_{L_{max.}}$)

Several theoretical investigations have been made of the effect of the ground upon the lift and drag of a wing.[4] These indicate that, for heights above the ground such as occur in the present tests, the greatest effect of the ground is an increase of effective aspect ratio; *i.e.*, a steepening of the curves of C_L *vs.* α and C_L *vs.* C_D. These effects are illustrated in Fig. 12, which is typical of the results obtained on all six models. The

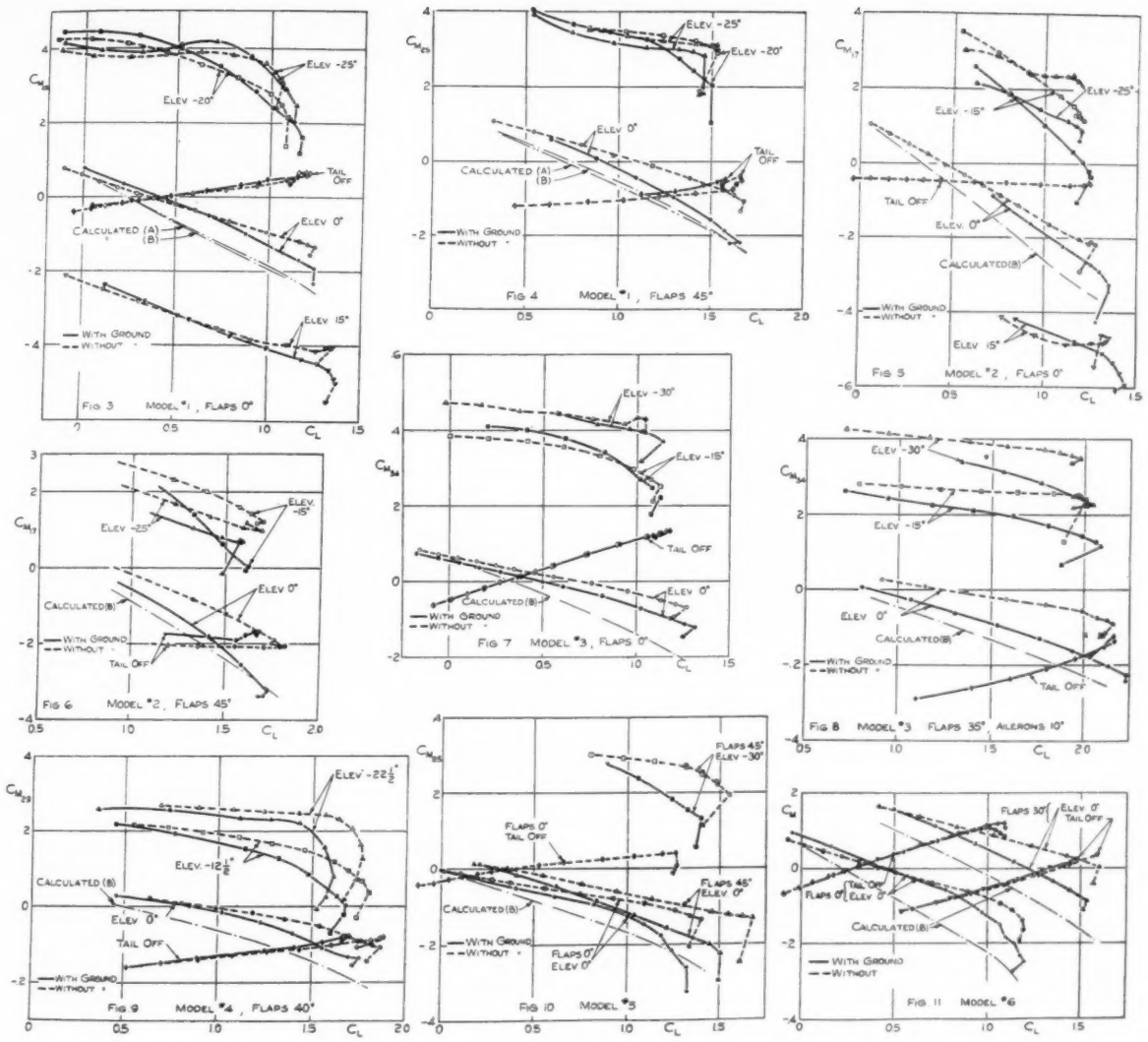
Table 1

Model Dimensions

Model	1	2	3	4	5	6
Main Wing { Aspect ratio, $A.R.$	8.87	9.95	7.79	7.43	6.68	6.96
Main Wing { Flap span, b_F/b	.50	.44	.50	.56	.41	.57
Horizontal Tail { Aspect ratio, $A.R._t$	4.00	4.44	5.06	4.59	3.94	4.22
Horizontal Tail { Area: S_t/S	.230	.168	.237	.150	.175	.225
Distance aft of c.g., $l_t/(b/2)$	.768	.723	.773	.790	.880	.907
Height of quarter-chord point of M.A.C. above ground plate, $H_w(b/2)$*	.14	.14	.24	.29	.23	.24
Height of elevator-hinge line above ground plate, $H_t/(b/2)$*	.16	.09	.22	.17	.15	.26
Reynolds Number (based on M.A.C.)	1.4×10^6	1.3×10^6	1.6×10^6	1.6×10^6	1.4×10^6	1.6×10^6

* These dimensions were measured at the angle of attack corresponding approximately to $C_{L_{max.}}$ with flaps down and ground plate in place. Since the wing-support trunnions were near the quarter-chord point in each model, the height H_w was nearly independent of angle of attack.

Notation: b = span of main wing, S = area of main wing.



FIGS. 3–11. Effect of ground upon pitching moment.

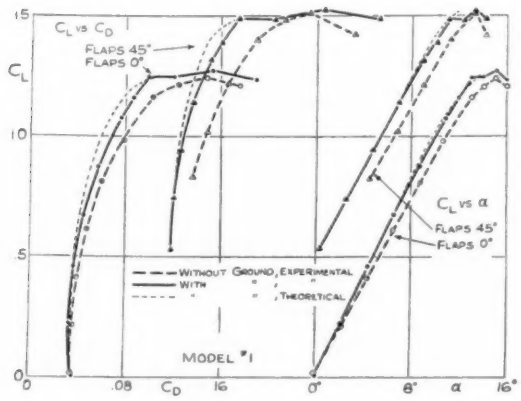


FIG. 12. Effect of ground upon lift and drag.

experimental curves both with and without ground have been corrected for wind-tunnel wall interference by the usual methods for circular tunnels. The theoretical curves have been obtained from the experimental curves "without ground" by the method of Wieselsberger,[5] using the height H_w (see Table 1) as the height of the wing above the ground. It should be pointed out that the wings of all the models tested had considerable dihedral angle, while the theory was derived for a straight wing.[6]

It will be seen that the agreement between the experimental and theoretical curves is rather poor so far as C_D is concerned, but quite satisfactory as regards α. The discrepancies between experiment and theory for the other models are very much the same as for Model 1.

TABLE 2

EFFECT OF GROUND UPON $C_{L_{max.}}$

	$C_{L_{max.}}$ no ground	$C_{L_{max.}}$ with ground	Increase due to ground
Model 1 Flaps 0°	1.25	1.25	0.00
Model 2 Flaps 0°	1.28	1.35	0.07
Model 3 Flaps 0°	1.37	1.41	0.04
Model 5 Flaps 0°	1.40	1.33	−0.07
Model 6 Flaps 0°	1.19	1.20	0.01
Model 1 Flaps 45°	1.67	1.65	−0.02
Model 2 Flaps 45°	1.81	1.73	−0.08
Model 3 Flaps 35° Ailerons 10°	2.16	2.22	0.06
Model 4 Flaps 40°	1.86	1.75	−0.11
Model 5 Flaps 45°	1.68	1.50	−0.18
Model 6 Flaps 30°	1.60	1.53	−0.07

V. EFFECT ON $C_{L_{max.}}$

At present there is no theory which predicts the effect of the ground upon the maximum lift coefficient. The results obtained in the tests described above are tabulated in Table 2. These are taken from the curves for elevators neutral.

VI. SUMMARY

(1) The principal effect of the ground on the pitching moments of an airplane, as determined by wind-tunnel tests using a fixed ground plate, is an increase in the slope $(-dC_{M_t}/dC_L)$ (where C_{M_t} = coefficient of pitching moment due to tail). This is accompanied by very little change of moment at zero lift, and either no change or a slight increase in stalling moment available from elevator deflection. The net result is a considerable limitation of the allowable forward travel of the center of gravity if trim is to be attained in the three-point landing attitude near the ground. The experimental results are not in close quantitative agreement with the present approximate theory.

(2) The "effective aspect ratio" of the airplane near the ground plate is greater than that away from the ground, as indicated by curves of lift, drag, and angle of attack.

(3) The maximum lift coefficient of the complete airplane model may be either increased or decreased by the presence of the ground plate.

APPENDIX

Explanation of Calculations for C_M Curves

The coefficient of pitching moment due to tail can be written as

$$C_{M_t} = -\eta_t K a_t(\alpha + \beta - \epsilon_t)$$

where

η_t = an empirical "tail efficiency factor" introduced to account for decreased velocity of the air over the tail surface, etc.
$K = S_t l_t / Sc$ = constant for any given airplane.
S_t = horizontal tail area.
l_t = distance from c.g. to aerodynamic center of horizontal tail.
S = wing area.
c = wing chord.
a_t = slope of lift coefficient curve of tail.
α = angle of attack of wing, measured from zero-lift angle.
β = angle of incidence of tail relative to zero-lift axis of wing.
ϵ_t = angle of wing downwash at tail.

If the subscripts g and 0 are used to represent conditions with and without ground, respectively, and elliptic lift distribution over the wing span is assumed, the change in moment coefficient at a given value of C_L becomes

$$\Delta C_{M_t} = C_{M_{t_0}} - C_{M_{t_g}}$$

$$= \eta_t K \left[a_{t_g}(\alpha_g + \beta) - a_{t_0}(\alpha_0 + \beta) + \frac{C_L}{\pi A}(a_{t_0}E_0 - a_{t_g}E_g) \right] \quad (1)$$

where

A = wing aspect ratio.
E = ratio of ϵ_t to angle of downwash at wing.

The ratio E is calculated under the assumption that the vortex sheet behind the wing is "rolled up" before reaching the tail position and that the rolled-up vortices are spaced $\pi b/4$ apart.[7] The appropriate equations of Glauert[8] are applied, and for the case with ground the downwash is the net value produced by both real and image wings.

The curves "A" of Figs. 3 and 4 have been obtained by use of the equation above. In these calculations the values of η_t have been determined from the slopes of the experimental C_{M_t} curves, and the values of a_{t_0} and a_{t_g} have been calculated for elliptic lift distribution

on the tail, using the method of Wieselsberger[5] for a_{t_g}. The curves "B" have been obtained by a simplified method based on the following assumptions:

(a) that $a_{t_g}(\alpha_g + \beta) = a_{t_0}(\alpha_0 + \beta)$. Actually $a_{t_g} > a_{t_0}$ and $\alpha_0(C_L) > \alpha_g(C_L)$, and the approximation is quite close;

(b) that $E_g = E_0 - E_t$ and $a_{t_g} = a_{t_0}$ in the last parenthesis, where $E_t C_L/\pi A$ is the angle of upwash at the tail due to the image wing only.

Under these assumptions

$$\Delta C_{M_t} = (\eta_t K a_{t_0}/\pi A)\cdot E_t C_L$$

$$= (\text{constant})\cdot E_t C_L$$ for a given airplane, and E_t is a function (from Glauert) only of the location of the tail above and aft of the image wing.

It has been implicitly assumed in Eq. (1) that η_t is the same near the ground as away from it. Although this assumption is doubtful, the empirical nature of the factor makes it difficult to estimate the effect of the ground in this regard.

References

[1] Millikan, C. B., and Klein, A. L., *Description and Calibration of 10-Foot Wind Tunnel at the California Institute of Technology*, presented at Berkeley meeting of A.S.M.E., Aeronautics Division, June, 1932.

[2] For a discussion of various methods of representing the ground, see: Le Sueur, Maurice, *Ground Effect on the Take-Off and Landing of Airplanes*, N.A.C.A. Technical Memorandum 771.

[3] Tani, Itokawa, and Taima, (Report No. 158 of the Aeronautical Research Institute, Tokyo) give experimental results for a low-wing monoplane (with elevators neutral) with and without flaps. The agreement with a theory similar to the present one is no better than that shown here; the Japanese authors' method of plotting makes the discrepancies less obvious.

[4] See La Sueur, Maurice (*loc. cit.*) and Pistolesi, E., *Ground Effect—Theory and Practice*, N.A.C.A. Technical Memorandum No. 828, for bibliographies.

[5] Wieselsberger, C., *Wing Resistance Near the Ground*, N.A.C.A. Technical Memorandum No. 77.

[6] A method of weighting H_w according to the lift distribution is suggested by Tani, etc., in Report No. 156 of the Aeronautical Research Institute, Tokyo. This method does not improve the agreement in the present cases.

[7] de Haller, P., *La portance et la trainee induite minimum d'une aile au voisinage du sol*, Mitt. Inst. Aerodyn., E.T.H., Zurich, No. 4/5, 1936, has shown that in the limiting case of a wing in contact with the ground, the lift distribution corresponding to minimum induced drag is parabolic rather than elliptical. Thus the effect of the ground upon the spacing of the rolled-up vortices is not great.

[8] Glauert, H., *The Elements of Airfoil and Airscrew Theory*, Chapter XII, Cambridge University Press, 1926.

Book Reviews

The Air Annual of the British Empire, 1938; edited by SQUADRON-LEADER C. G. BURGE; Pitman Publishing Corporation, New York & London, 1938; $6.00.

When this annual volume is received it offers such a temptation to spend hours in studying its many excellent chapters that it is difficult to know when to stop and commence to review it. Readers of the Journal who have used it as a standard reference work on aviation in the British Empire during its nine years of publication need only to be reminded that the 1938 edition is available. They will want it within arm's reach or, if they do not buy it themselves, will go to a library and learn from it the exact technical status of British aeronautics.

To those who are not familiar with its broad scope it can be said that its six hundred pages give the best idea of the materiel side of British flying that can be secured in any volume. The early chapters in which the Air Forces of the Empire are described by specialists are a masterly review of the progress made during 1937. The development of Civil Aviation in all parts of the Empire give the reader a picture of the far flung network of airlines that not only radiate from London but are gradually connecting all of the large centers of Empire industrial activity.

The chapters on Technical Developments are more than general papers prepared by specialists. They show that the editor has subdivided the whole field of aeronautics and secured experts on each subject to present the latest technical improvements that have been made. Then, as usual, the products of each company producing aircraft, aero-engines and aircraft components, materials, and rendering aerial services are given with the exact engineering data that makes the annual so indispensible. The pictures, which are numerous, are selected with rare discrimination, and are excellently printed.

Possibly the foregoing may seem fulsome, but when an annual which has always been worthy of praise continues to maintain and better its standards, its editors deserve unreserved commendation. It could well serve as a model for a technical annual which the Institute might sponsor at sometime in the future.

South by Thunderbird, by HUDSON STRODE; Random House, New York, 1937; 388 pages, $3.00.

The author has selected as part of his title the nickname the Indians call airplanes. The book is a delightful description of a flying circuit of South America—one that many Americans are finding so enjoyable.

Fortunately Norbourne, as the author refers to himself throughout the book, was a man who was not only interested in scenic attractions and flying experiences. He explored the political, social, and economic trends as he leisurely flew from country to country and makes the bold assertion on the cover "All you need to know about South America." While this may seem presumptuous at first glance, the reader, after enjoying nearly four hundred pages concerning the countries reached by Pan American Airways, will be ready to admit that it is about all that he cares to absorb vicariously. He wants to follow in Strode's footsteps hoping that his way will be made as easy and pleasant. The author is an experienced traveler, had excellent introductions, and describes many experiences that the casual traveler might not have. As has been said in many reviews of books that the Pan American loop has inspired authors to write, no traveler to South America over our famous international airline will ever want for descriptive guide books. *South by Thunderbird* adds another which will be invaluable for those who are planning a South American flight.

Institute Notes

Gifts to the Institute

Orville Wright has presented to the Institute a piece of the fabric from the plane they flew at Kitty Hawk. With it is the following inscription:

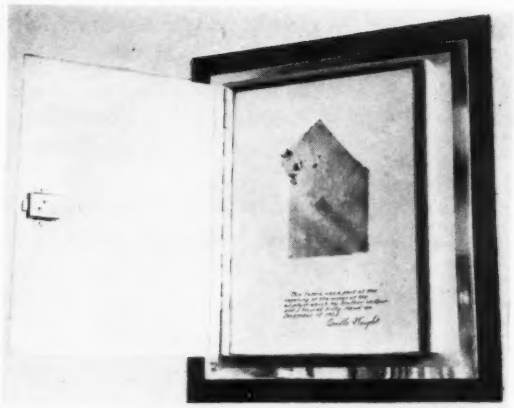
"This fabric was a part of the covering of the wings of the airplane which my brother Wilbur and I flew at Kitty Hawk on December 17, 1903.

Orville Wright"

The relic is such a valuable addition to the collection at the Institute that Glenn L. Martin agreed to make an aluminum case to protect it. The case is probably the finest example of aluminum workmanship ever made.

A model of the original Kitty Hawk Wright airplane has been acquired by the Institute from the Franklin Institute.

J. H. Kindelberger has presented to the Institute a model of a North American Observation Type airplane.



Wright relic and case.

Trip of President and Secretary

The President and the Secretary of the Institute visited the Institute Branches on the Pacific Coast during April. On the way they discussed plans for holding an Air Transport meeting in Chicago during October with William Littlewood, Vice-President of the Institute, and Major R. H. Schroeder of United Air Lines.

At Minneapolis, about three hundred members and guests of the Student Branch of the University of Minnesota met to hear Mr. Wright give a summary of the Institute's Sixth Annual Meeting, which was prepared and presented so that it gave in effect the present status of aeronautical engineering and research in the United States. Major Gardner showed the motion pictures of "A Visit to Langley Field" with suitable running comment. Professors Akerman, Piccard, and Barlow arranged a tour of inspection which included a visit to the offices and shops of the Northwest Airlines. Major Gardner was a guest passenger of the Northwest Airlines from Chicago to Seattle. Both the President and the Secretary were greatly impressed with the speed and comfort of the new Lockhead 14's.

In Seattle, Robert Minshall, Vice-President of the Boeing Aircraft Company, had a pleasant surprise for them. He said that a Branch had been formed in Seattle with the cooperation of the University of Washington and over three hundred engineers had applied for Affiliate Membership. In the evening over three hundred and fifty persons gathered in the Daniel Guggenheim Building of the University to hear Mr. Wright give his talk, substantially as presented the evening before in Minneapolis, and see the motion pictures, shown by Major Gardner.

The new Atlantic Clipper (the Boeing 314) was visited as well as the interesting new wind tunnel that Professors Kirsten and Eastman have recently put in operation at the University of Washington.

The next center visited was in the San Francisco area. Dr. Durand, Professor E. P. Lesley, Vice-President of the Institute, and Professors Reid and Niles gave the guests a dinner at Stanford University, after which the talks were repeated. At Oakland, the talks were given before the Boeing Schools of Aeronautics to about 300. Professor Folsom, of the University of California at Berkeley, arranged to have a showing of the motion pictures during the following week.

In the Los Angeles area, the Los Angeles Branch gathered at the Air Show and the talks were repeated. By special request the pictures were shown twice at the Curtiss-Wright Technical Institute. Visits were made to the California Institute of Technology and all the aircraft factories.

After leaving Los Angeles, Major Gardner made an interesting return trip, which he named the "Yucatan Loop." This trip was made through the courtesy of Pan American Airways. He flew from Los Angeles to Mexico City, and from there to Merida, Yucatan, where he spent a day visiting the restoration of the Mayan architectural wonders of Chichen Itza. He then flew to New York via Havana and Miami, the latter part of the trip through the courtesy of the Eastern Air Lines. He was away from New York eighteen days, did no night flying, did not fly on nine days, flew only mornings on all the other days except one, so that on a trip of eight thousand miles he was able to use all or a part of seventeen of the eighteen days for seeing friends.

This trip represents the first "President's Tour," a feature which was inaugurated this year and which it is hoped can be repeated each year hereafter.

Membership Notes

Dr. Th. von Kármán, an Honorary Fellow of the Institute, was recently elected to membership in the National Academy of Sciences.

Lt.-Comdr. P. V. H. Weems, an Associate Fellow of the Institute, has been awarded a cash prize and certificate by The Royal Society of Arts of London for the invention of the Second Setting Navigation Watch which has proved so useful to pilots in air navigation.

Necrology

Charles Grard

Inspecteur Général Grard, President of the French Corrosion Commission and an Associate Fellow of the Institute, died on November 8, 1937. He was born in Alençon, France, on December 4, 1870. He graduated from the Polytechnic Academy in 1891, and was an artillery officer until 1906. In 1914, he joined the Military Department of Aeronautics, and in 1925 became Inspecteur Général.

Although he retired from active service in 1933, he continued his aeronautical work teaching at the National Academy of Aeronautics.

Général Grard specialized in the field of metallurgy and published many books and papers on the subject. He was made a Commander of the Legion of Honor for his researches and studies on steels and alloys used in aeronautical construction and for other distinguished services. He organized the National Academy of Aeronautics and became its first Director. He always showed great interest in the work of the Institute and contributed several of his books to the library.

Book Reviews

The Aircraft Year Book for 1938, edited by HOWARD MINGOS; Aeronautical Chamber of Commerce of America, New York, 1937; 518 pages, ill., $5.00.

To say, each year, that the Aircraft Year Book becomes more interesting, is really repeating that the ever expanding American aircraft industry is producing a wider variety of types of aircraft, the accessory makers are developing gadgets of increasing usefulness, the air lines are becoming more stable, and all other aeronautical activities are increasing in scope and have a greater appeal to the public.

With this wider field to cover, Howard Mingos, the editor, has succeeded in giving a general review of the developments that occurred in 1937 in a style that is clear and informative. He has the rare quality of writing about technical matters so that they are readily understood by the layman.

Great emphasis is given to the precarious situation in which aeronautical research in the United States may find itself. The statements should be given careful consideration by all who are interested in national defense as well as aeronautical engineering.

"Meanwhile, although building planes and training airmen on an unprecedented scale, the European powers and Japan did not neglect their research and development programs. On the principle that air strength is not only superior numbers but is primarily superiority of equipment those powers undertook to keep at least abreast of one another. Their aerodynamic laboratories were undergoing extensive expansion at the beginning of 1938. The scientific staffs of these laboratories were being built up with the best talent available. Technicians were being placed on a par with air force pilots in the national scheme for preparedness, and air force pilots were the aristocrats of the armed services in countries where the military was supreme. This recognition of the importance of constant aerodynamic research was of unusual importance to the United States.

"In the United States aerodynamic research for years has been a model for the rest of the world to envy. It finally resulted in emulation. The scientists of other powers came to the United States and saw what Americans were doing, not only in their factory research and engineering laboratories but in the great Government laboratories maintained by the National Advisory Committee for Aeronautics. Then those foreign observers went home, to England, France, Germany, Italy, Russia, and Japan; and over a period of years they set up their own aerodynamic research plants on a scale never before attempted abroad, but which had for an incentive the work of the National Advisory Committee for Aeronautics in the United States and its cooperation with the American aircraft manufacturers. The proof of its value lay in the superiority of American planes, the performance of which is still unexcelled despite the breakneck speed with which other nations have been trying to improve their own equipment.

"At the beginning of 1938 it was apparent that the United States must increase its research and development work, both in the laboratories of the National Advisory Committee for Aeronautics and in the plants of its manufacturers. Otherwise, foreign powers, using all the means at their disposal, ahd these means seem unlimited, will develop aviation far beyond that stage which will be possible here."

The statistical excellence of the annual makes it the standard reference book on American aviation. It is noteworthy that this year's volume does not attempt to make comparisons of the strength of the air forces of the countries that have built extensive military and naval equipment. As comparisons based on numbers of aircraft were misleading in some ways, this omission is welcomed.

The review of the work and re-equipment of the Army, Navy, and Coast Guard is ample and brings readers up to date on the status of these services. Unless one is familiar with the extent to which aviation is used by other government departments there will be surprise in reading of the activities of seventeen agencies that have some interest in aeronautical development. In a short chapter the author gives the essential news of this work.

The chapter making the broadest appeal is naturally the review of the notable flights of 1937. It is significant that this is the shortest chapter in the book, an indication that there is perhaps less and less interest in the promotion of such flying.

The rapid growth of the air lines of the United States provides a record in which great pride can be taken. Not only is there great satisfaction to be felt in reading of the successful operation of the great network that crisscrosses the United States and extends its branches to foreign countries, but the forward looking policy of the air lines jointly and individually holds promise that the United States will maintain leadership in this highly competitive field.

Private Flying, Training and Education, Airways and Airports, and State Aviation Activities, all are given chapters which reflect expansion in the less dramatic phases of the well-rounded aeronautical development of any country.

The summary of the new equipment available to the governmental services, air lines, and private flying is as complete as is possible in an engineering field, where so great a part is held to be confidential and secret.

The aviation chronology, listing of records, the many pages of facts and figures regarding flying, and the directory of aviation personnel, as usual, make the Year Book serviceable for reference as well as for its readable chapters.

The twentieth year of publication should bring to the Aeronautical Chamber of Commerce of America deserved appreciation for preserving in such comprehensive form the current history of American aeronautics.

How, Why and When?—Aeroplanes, by R. BARNARD WAY; Cassell and Company Ltd., London, 1936; 126 pages, ill., $1.25.

The various forms which the books on aeronautics take seem to be endless. Books for youthful aviation enthusiasts have been published by the hundreds. But this author has treated his text in a new manner. Every right-hand page of the book contains a well-drawn sketch illustrating the subject matter on the left-hand page. Aeronautics is traced from its earliest historical beginnings and each step in its development is described in text and by picture. The descriptions are clearly and simply presented in interestingly brief chapters of one page each, which makes for easy reading. Naturally it shows many of the latest types of aircraft. The author suggests that his younger readers will learn more quickly about aircraft if they trace or copy his drawings—a unique suggestion.

It is an admirable book for boys to educate their parents in the art and history of aeronautics.

Books Received

The Institute expresses its appreciation of the gift of the following books by the McGraw-Hill Publishing Company for the Institute Library.

Engineering Mechanics—Statics, S. TIMOSHENKO and D. H. YOUNG; 334 pages, ill., $2.75.

Airplane Construction and Repair, JOHN E. YOUNGER; 433 pages, ill., $3.00.

Aerial and Marine Navigation Tables, JOHN E. GINGRICH; 64 pages, ill., $2.50.

Physics of the Air, W. J. HUMPHREYS; 654 pages, ill., $6.00.

Aerology, CHARLES JOSEPH MACGUIRE; 136 pages, ill., $2.50.

The Aircraft Mechanics' Handbook, I. W. MILLER; 174 pages, ill., $2.00.

The Airplane Engine, LIONEL S. MARKS; 454 pages, ill., $6.00.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Investigation of the Effect of the Propeller Slipstream on Downwash and Elevator Efficiency. H. B. Hemboldt. Effects of propeller slipstream on downwash and elevator efficiency were investigated separately. Efficiency factor was found to be smaller than the impact pressure ratio on the elevator and to be still further reduced by the nonsymmetrical flow on the control surfaces caused by the propeller. Applicable methods of evaluation and their fields of application are discussed and results of the evaluation compared with those from German and British model tests. Results serve for verification of existing downwash theories and the conformity is sufficient for practical results in normal cases. Report of the Ernst-Heinkel Aircraft Company. Luftfahrtforschung, January 20, 1938, pages 3–8, 8 illus., 1 table, 27 equations.

Recent Research on the Improvement of the Aerodynamic Characteristics of Aircraft. E. F. Relf. Profile drag measurements obtained in the compressed-air tunnel by use of the pitot-traverse method are discussed with special reference to the way in which the drag curves tend to follow the flat plate curve at high Reynolds numbers. Present American practice of using an "effective Reynolds number" to allow for turbulence effects is criticized. Recent results on drag of bodies measured in the compressed-air tunnel, interference drag, and drag tests of complete models are considered. Present position and problems to be solved in regard to longitudinal stability and lateral stability, both in normal flight and near the stall are outlined. Reasons why the present flutter theory may prove inadequate in the future are presented. Royal Aeronautical Soc., Preprint for Meeting, February 3, 1938, 18 pages, 6 illus.

Behavior of the Lift Distribution of a Wing about Singular Points of the Curves for Wing Plan Form and Angle of Attack. W. Pfeiffer. Method for determining the lift distribution about a wing is based upon a linear integral equation substituting a lifting line for the wing. A discontinuity or infinite point on the curves of the functions that determine wing plan form and angle of attack, or one of their differential quotients, is combined with a suitable singularity for the induced angle of attack, and also for the lift distribution. Behavior of lift distribution along the inner portion of the span and on the wing tips is taken up and lift distribution and aileron deflection is calculated. Luftfahrtforschung, October 20, 1937, pages 494–500, 12 illus., many equations.

The Neutral Moment Reference Point. A. Franke and F. Weinig. Stability investigations are simplified if the air-force moment can be referred to a point about which it remains constant. For a wing section in two-dimensional frictionless flow this reference point is accurately shown as fixed for all angles of attack. For an airplane, when drag is taken into consideration, this is true with sufficient accuracy for practical purposes only in the range of steady flow (before the breakaway). The authors show how this point can be calculated by means of measurements for a given mean angle of attack. DVL report. Luftfahrtforschung, October 20, 1937, pages 486–493, 11 illus., 5 tables, 40 equations.

New Equipment for Spinning Measurements. M. Kramer and K. B. Krueger. With the new DVL arrangement for spinning investigations, the usual rotation of the model about a fixed axis is replaced by the suitable rotation of the stream. The model moves during spinning measurements. Systematic results can be obtained quickly with the use of the standard three- or six-component balances, difficult compensation of forces due to mass is avoided, and flow behavior can be observed directly. DVL report. Luftfahrtforschung, October 20, 1937, pages 475–479, 11 illus.

Systematic Investigation of Profiles in the Large Wind Tunnels of the DVL. H. Doetsch and M. Kramer. Maximum lift of wings with and without split flaps and especially profile drag at low lift, including symmetrical 2-percent cambered NACA 00, 24 and 230 profiles in the thickness range of 9 to 21 percent. DVL results for maximum lift without landing flaps are compared with those of other tunnels over the entire practical flying range. Profile drag values at low lift were determined by means of the usual balance measurements and by measurement of momentum losses, and were extended to high Reynolds Number by investigation of profiles of unusually large chord. DVL report. Luftfahrtforschung, October 20, 1937, pages 480–485, 13 illus., 1 table.

Technical Notes. The Goettingen laboratory has constructed a "frosting" wind tunnel using air at −30°C. with sprays of water and artificial fog. Brief reference. Les Ailes, March 10, 1938, page 10.

The Way of a Seagull. Capt. J. Laurence Pritchard. "The more I study the way of an eagle in the air the more I am puzzled by the way of the designers of modern aircraft." Photographs reproduced show: a gull in a nearly stalled attitude with very little forward speed; a stalled turn; examples of gliding flight; a bird which has stalled just as it seized its food; and a gull braking hard as it comes down to take its food. Comments on the photographs are included. Flight, March 17, 1938, pages 256, 256a, 6 illus.

Aircraft Design

Aircraft Efficiencies. N. A. V. Piercy. Comparative efficiencies of lifting systems at small full scale, namely the gas-bag method used on airships, the fixed wings of airplanes and flying boats, and the autogyro rotor. Comparison is made between ideal propulsion and ideal wing lift; and skin friction and form losses are discussed. To be continued. Institution of Mechanical Engineers paper. Discussion of the paper is given in another article. Engineer, March 25, 1938, pages 346–347 and 338, 7 illus., 1 table Longer installment. Engineering, March 25, 1938, pages 339–342 and 331, 10 illus., 2 tables, 11 equations.

Method for Calculating Airplane Performance. A. Toussaint. Performance calculations for an airplane having an engine supercharged for constant power up to critical altitude and a propeller with variable pitch: $n = n_0$. Calculations are also given for the effect of the characteristics of the airplane on theoretical ceiling, maximum rate of climb, horizontal speed at the suitable regime, horizontal speeds at different altitudes when the engine is not supercharged, and horizontal speeds at different altitudes above the critical altitude in the case of an engine supercharged for constant power. Continued. La Technique Aéronautique, No. 146, 1937, pages 267–281, 3 illus., 3 tables, 33 equations.

Problems of High Speed Flight as Affected by Compressibility. C. N. H. Lock. Points of high local velocity at which the local velocity of sound may be exceeded should be avoided in the design of aircraft for high-speed flight. In concluding the author compares the lenticular, elliptic and thin circular airfoils and the spheroid, considers the complete airplane, indicates the points at which maximum velocities are likely to occur, and how they are to be reduced, and takes up problems of engine cooling and propeller design. The paper deals with the effect of compressibility of air on bodies moving through it at speeds ranging from the velocity of sound (710 m.p.h. at high altitude) as an upper limit to a lower limit ranging from a half to three quarters the velocity of sound. The discussion covers photographs of shock waves in the American high-speed wind tunnel, experiments with high-tip-speed model propellers, the NPL high-speed tunnel and experimental results obtained in it, the balance measurements in the American high-speed tunnel. Journal Royal Aeronautical Soc., March, 1938, pages 193–219 and (discussion) 220–228, 22 illus., 4 equations.

Technical Notes. Optimum characteristics for a transatlantic flying boat capable of covering a distance of 7500 km. with a specific fuel consumption of 230 gr./hp-hr. Results of calculations made by L. Bréguet are given showing a total load of 28,000 kg. for an airplane carrying 8 passengers with their baggage and 800 kg. of mail. Les Ailes, March 10, 1938, page 10.

Wind-Tunnel Investigation on Aerodynamic Brakes. D. Fuchs. Air brake should be fitted on the lower surface of the wing near the front spar, and, under these conditions, an additional tail-heavy couple reducing the diving moment is introduced. A slot located between brake and wing reduces troublesome effects of the wake without influencing the braking action. The investigation covers: arrangement of the braking surface on the wing by attachment to the upper wing, by modification of the aspect ratio, and by displacement in a lateral direction; influence of slots between wing and flap on the aerodynamic properties of a complete airplane model and of a rectangular wing; and pressure distribution on a profile with air brakes. Report of the Ernst-Heinkel Aircraft Company. Luftfahrtforschung, January 20, 1938, pages 19–27, 13 illus.

A New Form of Biplane. H. B. Irving. Special form of biplane described in R. & M. 1715 was further investigated by tests on a complete flapped model. It was found that keeping the upper wing straight in end view leads to a rather high effective dihedral if relative disposition of the tips of the upper and lower wings is kept as in the experiments described. Special advantage of stability in roll up to angles of incidence as high as about 40° was confirmed, although effect of flaps on increasing the lift was a disappointing feature of the tests. Aircraft Engg., January, 1938, pages 14–16, 8 illus.

The Sinking Speed of Aeroplanes. B. Lundberg. Construction of a general scale for the sinking speed is described in detail. Curve for the sinking speed as a function of the forward velocity, when plotted on logarithmic paper, has a quite general geometrical form, and it is possible to make a general scale for the curve which can be placed over the logarithmic diagram to different positions corresponding with the arbitrary qualities of a given airplane. Method is suggested as an alternative to horsepower required for use in performance calculations. Calculation of the aerodynamic properties of an airplane by gliding tests is also explained. Concluded. Aircraft Engg., January, 1938, pages 7–10, 2 illus., 27 equations.

What is a true streamline? In the Miles Whitney Straight which is being used for experimental research, thickness of the blown-out section of the wing is 30 percent of the chord. A thickness of 40 percent of the chord has actually been successfully flown. Photograph only. Aeroplane, March 2, 1938, page 248, 1 illus.

Stress Analysis and Structures

The Different Types of Wing Construction and the Tubular-Spar Wing R. Vogt. Tubular-spar wing is a real single-spar wing where the torsion-carrying fibers are combined with the bending member. This construction is used in the Hamburger Ha. 139 flying boat which has a span of 27 meters and gross weight of 17 metric tons. The tubular spar can carry higher "friction stresses," its exact location within the wing contour is of minor importance, and highly-concentrated local loads may be introduced. Author is Chief Engineer of the Hamburger Flugzeugbau G.m.b.H. Aeroplane, March 2, 1938, pages 254–257, 9 illus.

Openings in Stressed-Skin Wings. D. Williams. Effect of cover discontinuities on strength and stiffness of stressed-skin wings, such as major gaps occasioned by housing of gasoline tanks or undercarriage wheels. Formulas are derived for the torque concentrated at the free end, for a torque uniformly distributed along the whole span, and for torsional deflection of the tube. It is shown that position of the gap that produces greatest stress is not the one that is productive of the greatest loss of stiffness, the position being dictated by the relative importance of stiffness and strength in the particular design. Aircraft Engineering, January, 1938, pages 3–6, 6 illus., 65 equations.

Solving Space Structures Graphically. E. Moness. An engine mount structure is solved graphically by means of the method described in the December, 1937 issue. The structure is treated as a true space structure and all the members at any joint are dealt with simultaneously, regardless of their direction or of the planes in which they lie. Aviation, March, 1938, pages 28–29, 68, 70, 6 illus.

A Stressed-Skin Problem. W. J. Goodey. Nature of the stress distribution in the immediate neighborhood of applied loads or constraints. General theory is discussed for the case of a rectangular tube of constant cross section built in at one end and having a torque applied at an intermediate section. The theory is then applied to determine the stress distribution in a two-spar skin-covered rectangular box, the skin being reinforced with longitudinal stiffeners or stringers which will contribute to the bending strength of the box. Aircraft Engineering, January, 1938, page 11–13, 5 illus., 16 equations.

The Elastic Cantilever Bar. J. Cassens. Failure of bar frameworks due to buckling, and a method for determining rapidly the value of the constraint exerted on the bar in compression by adjacent bars in a fuselage or wing structure. A strict graphical solution of the problems is given in a diagram, and an approximate analytical method is shown with the help of

which it is possible to obtain at once a relatively easy solution in the non-elastic range. Errors of the approximate solution are small. Luftfahrtforschung, October 20, 1938, pages 501–510, 12 illus., 4 tables, 29 equations.

Aircraft

Aeroplanes of the Month. Focke-Wulf F.W. 200 Condor 25-passenger transport (four B.M.W. 132 Dc 9-cylinder radial engines, maximum sea level speed of 232 m.p.h.). Savoia Marchetti S.79 five-seater high-speed long-range bomber (three Alfa Romeo 126 RC-35 9-cylinder radial engines developing 780 hp. for take-off, maximum speed 280 m.p.h. at 13,120 ft.). Koolhoven F.K. 56 two-seater enclosed light military reconnaissance monoplane (Wright Whirlwind R-975 E.3 engine, maximum speed 186 m.p.h. at 1640 ft.). Caproni 310 Libeccio six-passenger light transport (two Piaggio P.VII C.16 7-cylinder radial engines, maximum speed 218 m.p.h. at 5249 ft.). Ryan SC-145W three-seater light airplane. Construction, characteristics, performance, drawings, photographs. Aeroplane, March 2, 1938, pages 258–259, 10 illus., 5 tables.

The Blenheim Gets Going. An average speed of 288 m.p.h. was recently made by a Blenheim medium bomber and the general belief is that the maximum speed is nearer 300 m.p.h. than the 280 m.p.h. given. The French Potez 631 fighter light bomber on order for the Armée de l'Air is credited with a top speed of only 285 m.p.h. Brief reference. Flight, March 3, 1938, page 212.

Two-Seater Fighters—Will They Survive. H. F. King. "For certain duties the larger multi-seater, on the lines of the American Bell Airacuda, may be adopted, though this type, with its lateral as well as fore-and-aft armament, is condemned by some who say it marks a return to the multi-place de combat theme, and that the big 'battle wagon' is impracticable due to restrictions on lateral fire." Other references are made to the Airacuda. The twin-engined fighter is thought likely to be a three-seater. A drawing and a few details are given for the unorthodox French Delanne airplane which has an estimated top speed of 370 m.p.h. This airplane is armed apparently with a shell-gun mounted on the Hispano-Suiza Series Y engine, two more guns on the wings, and a second shell gun in the rear where its field of fire is exceptionally good. It may be regarded as a very heavily staggered biplane with no tail, the cockpits being located in the rear. Trends of France, Holland, Italy, and the United States in regard to the two-seater fighter are discussed. Flight, February 17, 1938, pages 154–156, 4 illus.

British Light Aircraft. Review of twenty British makes giving their characteristics and capabilities, cutaway drawings, and photographs. Foreign types (American, German, and Latvian) available on the British market are covered in a second shorter article, while a third describes British engines up to 400 hp. A fourth article, entitled "Other Peoples Aeroplanes," discusses design trends in American, German, Belgian and Italian light airplanes, and credits America with leading in the ultra-light field (up to 50 hp.). Flight, March 24, 1938, pages 274–282, 284–285, 286h, 287–291, and 294–295, 43 illus., 1 table.

New Four-Engined Airliners. R. S. Findley. DeHavilland Albatross, Armstrong-Whitworth Ensign, Junkers Ju-90, Douglas DC-4, and Boeing 307 transports. Few details of each. U.S. Air Services, March, 1938, pages 24–25, 36, 4 illus.

Canada

Noorduyn Norseman. Nine-passenger high-wing monoplane designed and built to meet the variety of conditions encountered by the commercial operator in Northern Canada. Powered with a Wasp S3HI 550-hp. engine the airplane has a maximum speed of 170 m.p.h. at 5000 ft. Few details. Aviation, March, 1938, page 33, 1 illus., 1 table.

France

Airplanes in Test. First issue—Brief description of tests of the Bréguet gyroplane in parachutal descent with rotor in autorotation. Very brief references only are made to the following French military aircraft undergoing tests: Marcel-Bloch 170 combat and light bomber (two Gnôme Rhône 14-No. 940-hp. engines); Marcel-Bloch 150 single-seater pursuit (two wing cannons and new Gnôme Rhône engine of higher power); Nieuport 161 single-seater pursuit (Hispano-Suiza 12-Ycrs 860-hp. engine-cannon); and Morane-Saulnier 350 single-seater acrobatic training biplane.

Second issue—Brief references to the following: Marcel-Bloch 170 combat and light bomber; Hanriot 230 airplane for training in piloting modern bimotored airplanes; Latécoère 523 No. 2 38-ton flying boat (six Hispano-Suiza 12-Y 960-hp. engines); Potez 56-6 T.3 observation airplane; and Potez 630 fighter-commander (new Hispano-Suiza 14-AB 650-hp. engines). Les Ailes, March 10 and 17, 1938, pages 9 and 8.

French Aircraft. Caudron-Renault C-685 Rafale 1936 single-seater sport (Renault 6-903 240-hp. air-cooled engine, top speed 392 km./hr. at 2000 meters), the C-690 pursuit trainer (same engine, top speed 378 km./hr at 2000 meters), and the C-720 pursuit trainer (Renault 4 Pei 140-hp. engine, top speed 280 km./hr.). S.F.C.A. Lignel-20 racer (Renault 6-903 220-hp. engine, top speed 390 km./hr. at 2000 meters), the Maillet-20 tourist airplane (Regnier R.6 180-hp. engine, top speed 290 km./hr.), and Le Taupin light airplane (Mengin 2A01 32-hp. engine, top speed 110 km./hr.). Mauboussin 123 two-seater trainer and sport airplane (Salmson 9 Adr 60-hp. engine, top speed 165 km./hr.). Characteristics, performance, drawings, and photographs. La Technique Aeronautique No. 146, 1937, pages 238–251, 14 illus.

The Lioré-et-Olivier LeO H-246. Thirty-seater high-wing cantilever flying boat is powered by four Hispano-Suiza 12-Xfrs 12-cylinder liquid-cooled engines and has a maximum speed of 206 m.p.h. at 6560 ft. Range is 930 miles and payload 6460 lb. Construction, dimensions, weights, loadings, and performance. Aeroplane, March 23, 1938, page 362, 2 illus., 1 table.

A Modern French Airplane. Potez 631 combat and light bombardment airplane (equipped with two Gnôme Rhône M-14 engines) flies at 460 km./-hr. at 6200 meters and climbs to 4200 meters in 5 min. 56 sec. Photographs only. Les Ailes, March 17, 1938, page 1, 3 illus.

New Ideas in France. Photograph of the New Potez 6-141 reconnaissance flying boat and caption referring to the casemate or sponson to house a gun in the side. Aeroplane, March 16, 1938, page 330, 1 illus.

Night Bombers. Group of Farman 223 night bombers in flight. These planes are in production. Drawing only. Les Ailes, March 10, 1938, page 1, 1 illus.

Technical Notes. Amiot 340 bomber (two Hispano-Suiza 12 Y 1200-hp. engines) will have a speed of 560 km./hr. at 4000 meters, ceiling of 10,000 meters, range of 2500 km. at 420 km./hr., weight empty 4500 kg., and useful load of 4500 kg. This performance has been realized with the Amiot 340 equipped with two Gnôme Rhône P-14 engines developing 1500 hp. at 4500 meters. Brief reference. Les Ailes, March 17, 1938, page 7.

Airplanes in Test. Morane-Saulnier M.S.405, Romano R-150, Latécoère 523 seaplane (six Hispano-Suiza engines), LeO-45 bomber and LeO-46 seaplane. Very brief references to these military airplanes. Les Ailes, March 3, 1938, page 9.

Amiot 340 High-Speed Bomber. A. Frachet. A military version of the Amiot 370 which holds records over 2000 km., the Amiot 340 bomber is powered by two Gnôme Rhône 14 No. 1000-hp. engines, carries a load of 1500 kg., and has a maximum speed of 490 km./hr. Description, characteristics, performance. Les Ailes, March 3, 1938, page 9, 3 illus., 2 tables.

French Aircraft. P. Léglise. Entire issue is devoted to descriptions or in some cases a few details of French military and commercial aircraft with drawings and photographs. The following military aircraft and new large transports are included: Bréguet Vultur bomber and the 690 three-seater pursuit. Caudron Renault C.710 single-seater pursuit, and C.690 single-seater pursuit. Latécoère 298 torpedo seaplane, 570 bomber, 611 naval seaplane, and 631 transport. Morane-Saulnier M.S.405 single-seater pursuit. Mureaux 180 C.2 two-seater fighter. Amiot 150 B.E. twin-engined bomber, and the 370. Farman 223 four-engined bomber and four-engined 2231. Hanriot H.220 three-seater twin-engined fighter and H-230 twin-engined trainer. C.A.M.S. 161 six-engined transatlantic flying boat. Potez 63 three-seater fighter, the 66 four-engined transport, the 661, the 662, and the 566 T.3 reconnaissance. Loire-Nieuport 20 multi-seater fighter, Loire 102 flying boat, Loire 130 reconnaissance seaplane, and Loire 210 single-seater pursuit seaplane. Lioré et Olivier LeO.45 bomber, S.N.C.A.-S.E.200 six-engined transatlantic flying boat, and LeO.H.246 four-engined commercial flying boat. Bloch 131 bomber, 150 single-seater pursuit, 161, the 162 four-engined attack plane, 134B and the 170 twin-engined two seater. Bleriot construction for pursuit airplanes. Zodiac M.B.Z.3 motorized balloon.

In a catalog of aeronautical products included in the advertising section of this issue, characteristics and performance are given in both French and English for 29 French and other military and commercial aircraft and 14 aircraft engines. A number of aeronautical accessories and equipment are mentioned.

Attached to the cover of the magazine is a supplement entitled the French aeronautic industry at the beginning of 1938. L'Aéronautique, December, 1937, pages 271–332, many illus.

Outsize Fashions from France. Air-Wibault 670 66-passenger low-mid-wing cantilever monoplane (four 1600-hp. Gnôme-Rhône P.18 two-row radials cantilevered out from the wing). Bréguet 760 56-passenger airplane (four 1000-hp. engines). Latécoère 631 flying boat (six Gnôme Rhône P.18 engines delivering 1650 hp. each for take-off), whose characteristic feature is the lowering of the outboard engine nacelles which accommodate in their tail fairings the hydraulically retracted floats. Lioré et Olivier and Romano S.E.200 flying boat (six Ghôme Rhône P.18 engines). C.A.M.S. 161 flying boat (six liquid-cooled Hispano-Suiza 12 Ydrs. engines delivering a total of 5520 hp. at 1500 meters). A few details regarding each. Flight, March 3, 1938, pages 203–204, 5 illus.

The Four Winds. The Dewoitine concern is said to be building an airplane with a range of nearly 12,500 miles for an attempt on the world's distance record. Brief reference. Flight, February 17, 1938, page 160.

Over the Mediterranean. LeO H-246 four-engined flying boat transporting 26 passengers at 270/290 km./hr. which will be placed in service by Air France this year. Photographs of prototype. Les Ailes, March 3, 1938, page 1, 3 illus.

Record-Bandying. Records for speed over 2000 km. without load and respectively with 500, 1000, and 2000-kg. load, were broken by Rossi and Vigroux on February 8 with the Amiot 370 monoplane (two Hispano-Suiza 850-hp. V-12 engines). Average speed was 436 km./hr. Equipped with 1200 Hispano-Suiza engines, special Ratier propellers, and a new type of radiator for liquid-cooled engines, the airplane is expected to do 540 km./hr. References to the record flight and to claims that a Savoia S.79 recovered the records. Aeroplane, March 2, 1938, page 246.

Germany

A German Long-Range Aeroplane. Heinkel He-116 airplane described is equipped with four Hirth 508-B 240-hp. engines, carries a crew of four, 1214 lb. of mail and enough gasoline for a range of 2800 miles at a cruising speed of 186 m.p.h. Aircraft Engineering, January, 1938, page 17, 3 illus., 1 table.

Helicopter Hopes. In the Focke-Wulf F.W.61 helicopter, drive to the two rotor heads is by bevel gears, friction clutch and inclined shafts. Blades are hinged to the rotor heads and have their angle of incidence controlled in such a manner that the rotors provide all control with the exception of directional. Rate of climb is high and exceeds by far that of the autogiro. Brief editorial comment. Flight, March 3, 1938, page 197.

Buecker Bue-180 "Student" Light Airplane. A. Frachet. Two-place low-wing monoplane designed for the preliminary step in training glider pilots in the operation of airplanes. Powered with a Walter Mikron II 60-hp. engine the airplane has a top speed of 175 km./hr., and range of 650 km. at 160 km./hr. cruising speed. Long description. Les Ailes, March 10, 1938, page 9, 3 illus., 1 table.

The Dornier Do.24. Ocean-going three-engined high-wing monoplane flying boat having a maximum speed of 195–210 m.p.h. according to the power unit (three 700 to 900 hp. engines). Range is 2175 miles. Internal layout is designed entirely for military duties, there being three enclosed gun positions, one in the nose, one in the middle of the hull, and a third in the tail. Few details. Aircraft Engineering, March, 1938, page 83, 4 illus., 1 table.

Events Abroad—Germany. Dornier 17 twin-engined bomber, Me.109 and He.112 single-seater fighters,and the Fi.156 for communication duties. Very few details of these airplanes which were exhibited at the Zurich Show. Cruising speeds only are given for the Dornier 17 and 18, Heinkel 70 and 111, and Junkers 52 and 86, these commercial airplanes having military counterparts in the German Air Force. Brief note. Royal Air Force Quarterly, January, 1938, pages 93–94.

A German Dive Bomber. New Junkers Ju.87 two-seater dive bomber (680-hp. Jumo 210 inverted vee-12 gasoline engine) has a specially strong air brake fitted to restrict speed during a diving attack which may be made with 500 or 1000 lb. of bombs. Photograph only. Flight, March 17, 1938, page 258, 1 illus.

On the Way. Photograph of a flight of Junkers 86s (Junkers Jumo 205 Diesel engines) of the German Air Force, with caption calling attention to the direction-finding radio loops with which they can home on any broadcasting station. Aeroplane, March 16, 1938, page 319, 1 illus.

Technical Notes Deutsche Lufthansa is waiting for a modernized version of the Dornier Do-X of 40 tons. Brief reference. Les Ailes, March 10 1938, page 10.

GREAT BRITAIN

More About Monoplane Fighters. Hawker Hurricane multigun monoplane fighter is said to show a gain in speed of at least 80 m.p.h. in comparison with the "swiftest biplane fighter," (obviously the Gladiator which does about 250 m.p.h.). Brief reference. Flight, March 24, 1938, page 299.

No. 76 (B.) Squadron. Major F. A. deV. Robertson. The Vickers Wellesley medium bomber (Pegasus XX engine developing 925 hp. at 10,000 ft.) has a top speed of 216 m.p.h. with full military load, range of 1620 miles, and ceiling of 31,000 ft. Article gives the history of the Squadron which was the first to have this bomber, and only mentions a few details of the bomber. Flight, March 17, 1938, pages 256e–256g, 4 illus.

A Crop of British Prototypes. References only are made to the Heston and Miles *ab initio* trainers of entirely new design and wooden construction, and to the Armstrong-Whitworth Whitley IV heavy bomber powered by two Rolls-Royce Merlin engines, which may be of the Merlin X series with two-speed blower, power figures for which are given. Recent types of Bristol engines are referred to, including three experimental Hercules, and new Perseus and Pegasus models. Ratings of the Perseus series VI, VIII, and XII are given. Flight, March 3, 1938, page 204.

Ducal Dignity. First production-type Vickers Wellington I medium bomber built on the geodetic principle and powered with two Bristol Pegasus XVII radials with two-speed blowers. Nose and tail turrets have been revised. Few details of changes made over the prototype. Flight, January 6, 1938, pages 21, 2, 9, 3 illus. Aeroplane, January 5, 1938, pages 1, 2, 2 illus.

Second Parting. Separation of the two components of the Short-Mayo composite aircraft in flight took place with ease and smoothness and almost mathematical precision. Visual and cinematographic evidence showed there was no relative movement in a horizontal plane until the machines were some 50 ft. apart and there was no trace of any yawing of the two aircraft in relation to one another. Short account of public demonstration, and extracts from "British Movietone" slow motion film, as well as editorial comments. Flight, March 3, 1938, pages 209, 197, 13 illus.

Three stages of separation are outlined. Engineer, March 4, 1938, pages 254, 250, 2 illus.

Description of demonstration as well as criticism of the principle of launching a high-speed aircraft from a slow one. Aeroplane, March 2, 1938, pages 266–267, 7 illus.

Short Mayo. Explanation of how the lift is shared between the Mercury and Maia components of the composite aircraft recently tested, and the principles involved in their separation. The two components are described in detail with structural and cutaway drawings illustrating the interiors, and photographs. Details of the hook release are shown in a drawing and other special equipment for unhooking is discussed. Possibilities of this type of aircraft are considered. Components and accessories of the two airplanes are listed. Flight, February 17, 1938, pages 158a–158h, 159, 14 illus.

On the Mayo Composite Aircraft. C. G. Grey. Mr. Grey criticizes this method of launching an aircraft for long-distance flights, and in particular the upper component Mercury as a high-speed airplane to fly the Atlantic. A second article describes the aircraft in great detail, giving cutaway and structural drawings, a drawing of the release gear, and sketches to show how the separating force is derived. Aeroplane, February 16, 1938, pages 195–201, 11 illus., 2 tables.

A Service High Speed Flight. A Hawker Hurricane single-seat fighter (990-hp. Rolls-Royce Merlin engine) has been flown by Squadron Leader J. W. Gillau at an average speed of 408.75 m.p.h. over a distance of 327 miles. Brief note and editorial comment stating this is not the true speed of the airplane. Aeroplane, February 16, 1938, pages 191, 206, 2 illus.

Training for Tomorrow. A pilot's experiences in flying the Miles Magister; the first basic trainer of the new era and a low-wing monoplane having a full aerobatic C. of A. Special reference is made to spinning tests of the airplane. Flight, March 3, 1938, pages 198–200, 3 illus., 1 table.

Take-Off of Heavily-Loaded Aircraft by Means of the Mayo Composite Aircraft Method. P. Leglise. Criticisms of the Mayo method of launching heavily-loaded aircraft include the psychological conditions involved, and lack of knowledge of the interferences and slipstreams of the propellers. Long detailed description of the Mayo composite aircraft. Rev. de l'Armée de l'Air, December, 1937, pages 1337–1358, 6 illus., 2 tables.

Vickers Supermarine Scapa. Supermarine flying boat recently produced in series for the R.A.F. for reconnaissance, bombardment, torpedo carrying, and training in navigation. The flying boat is powered by two Rolls Royce Kestrel III M.S. engines. Description. Rev. de l'Armée de l'Air December, 1937, pages 1402–1407, 4 illus.

HOLLAND

The Fokker T.5. Heavily-armed long-range midwing bomber or "Battle Plane." Powered with two Bristol Pegasus XXVI engines, the prototype has a maximum speed of 242 m.p.h. at 10,000 ft. and range of 900 miles. Plexiglass turret in the nose may be armed with a 20–25 mm. cannon or two machine guns and is occupied by the commander-navigator-bomb aimer. Pilot is located in a cockpit ahead of the wing, second pilot behind in a cockpit with a gun position over the wing. Radio operator's post is in line with the wing trailing edge and contains a gun firing downward, and fifth member of the crew is stationed in the extreme rear of the fuselage in a rotatable Fokker conical turret. Long description. Aircraft Engineering, March, 1938, pages 83–84, 3 illus., 1 table.

With two Gnôme Rhône 14N-01 engines maximum speed of the Fokker T.5 is 425 km./hr. at 4900 meters and range 1500 km. Long description of construction and armament, and table of weights and performances. Rev. de l'Armée de l'Air, December, 1937, pages 1407–1412, 7 illus., 1 table.

The Fokker S-9. Biplane trainer may be powered with the 165-hp. Armstrong-Siddeley Genet Major radial, the 168-hp. Menasco Buccaneer inverted inline, or the Bramo Sh-14-A radial engine. Powered with the Armstrong-Siddeley, the airplane has a maximum speed of 111.7 m.p.h. at sea level and range of 390 miles. Construction, dimensions, weights, loadings, and performance. Aeroplane, March 23, 1938, page 362, 2 illus., 1 table.

Some New Features of the Fokker G.1. Opinions of Captain Magnusson of the Finnish Air Force on performance of the Fokker G.1, especially in a dive. A three-seater version of the G.1 equipped with Bristol engines is to be tried out, according to the Fokker Company. Brief note with photograph of the pilot's cockpit. Rev. de l'Armée de l'Air, December, 1937, pages 1412–1413, 2 illus.

Fokker S-9 Trainer. Two-place biplane for training personnel of the Royal Dutch Navy has been designed for power derived from an inline 168-hp. Menasco Buccaneer B-6 engine, although either a 165-hp. Armstrong-Siddeley Genet Major, or 160-hp. Siemens SH-14A radial engine may be used. Powered with the Buccaneer, the airplane has a maximum speed of 118 m.p.h. Description. Aero Digest, February, 1938, page 98, 1 illus., 1 table.

The T.5 Tested and Camouflaged. Powered by two 850-hp. Bristol Pegasus XXI radials and D.H.v.p. propellers, the Fokker T.5 heavy bomber reached 259 m.p.h. at 13,120 ft. The bomber has been ordered in quantity by the Royal Dutch Air Force. Brief reference. Flight, March 3, 1938, page 212.

ITALY

Bomber Performance. A specially prepared Savoia Marchetti S.79 recently covered 621 miles with a load of 4410 lb. at an average of 280 m.p.h. Newest version is being fitted with two-row Alfa Romeos. Brief reference. Flight, March 17, 1938, page 258.

The Breda 65 Two-Seater Combat Airplane. Low-wing fighter and bombardment airplane powered by an Isotta-Fraschini A.80 RC.41 900-hp. engine driving a Fiat variable-pitch propeller. Maximum speed is 425 km./hr. Few details. Rev. de l'Armée de l'Air, December, 1937, page 1416, 2 illus.

U. S. A.

"B" and "SO." "Though fantastic figures have been advanced by imaginative newspapermen for the speed of this type" the U.S. Army's YB-17 "it is probable that the maximum is in the region of 230 m.p.h." View from below of the YB-17 during a landing approach with flaps down, and a view of Navy Curtiss SOC-2 floatplanes "in highly creditable formation." Flight, March 17, 1938, page 256h, 2 illus.

Batwing Ready for Tests. Two-place midwing tailless airplane with tricycle landing gear. Vertical surfaces at the wing tips serve as rudders and air brakes and long tapered ailerons act as elevators in addition to furnishing lateral control. Trimming tabs are fitted to outer ends of each aileron-elevator. The airplane is powered by a 75-hp. Pobjoy engine driving a pusher propeller. Estimated top speed is 150 m.p.h. Western Flying, March, 1938, 1 illus.

Boeing South Seas Clipper Nears Completion. New Boeing 314 72-passenger long-range flying boat ordered by Pan American Airways. Description. U.S. Air Services, March, 1938, page 29, 1 illus.

Curtiss Military Airplanes. Curtiss Y1A-18 twin-engined combat, P-36 pursuit, SB-C3 bomber and reconnaissance, and the SB-C3 observation and reconnaissance airplanes. Few details of each, including armament of the Y1A-18. Rev. de l'Armée de l'Air, December, 1937, pages 1414–1415, 2 illus.

PX's. Development of radio-controlled miniature aircraft for antiaircraft target practice is being continued in Hollywood and tested by a local Army unit. Brief ref. Western Flying, March, 1938, page 36.

Abram's "Explorer." Abrams Strato-plane Explorer is designed for photographic mapping and has exceptional forward and downward visibility for the pilot and oxygen-equipped quarters. Powered with a 330-hp. Wright Whirlwind, the airplane has a maximum speed of 200 m.p.h. at 10,000 ft., rate of climb of 1800 ft./min., service ceiling 21,000 ft., and cruising range of 1400 miles. Long description. Aero Digest, February, 1938, page 62, 2 illus., 1 table.

American Planes and Engines for 1938. Review covers 179 civil and military aircraft giving photographs, three-view drawings, characteristics, and performances except in the case of some military aircraft. Aviation, February, 1938, pages 35–63, many photographs, drawings, and tables.

Bellanca Junior. Models 14-7 and 14-9 three-place cabin monoplanes powered by LeBlond engines, Model 14-7 with a 5E 70-hp. engine having a maximum speed of 115 m.p.h., and the Model 14-9 with a 5F 90-hp. engine having a top speed of 120 m.p.h. Description, specifications, and performance. Aero Digest, February, 1938, page 53, 2 illus., 3 tables.

Cessna "Airmaster" for 1938. Four-place cabin monoplane is an improved but basically similar version of the C-37. Powered by a 145-hp. Warner Series 50 engine it has a maximum speed of 162 m.p.h. Long description. Aero Digest, February, 1938, page 66, 3 illus., 1 table. Western Flying, March, 1938, pages 24, 28, 1 illus., 1 table.

Dart Model G 90-Hp. Monoplane. Monosport Model G two-place low-wing cabin monoplane powered by a Lambert R-266 90-hp. engine and having a maximum speed of 130 m.p.h. Description. Aero Digest, February, 1938, page 58, 2 illus., 1 table.

DC-4 Takes Shape. Douglas DC-4 four-engined 42-passenger airplane will have a gross weight of 64,000 lb., and useful load of 20,000 lb. Top speed will probably be above the 220 m.p.h. mark at critical altitudes. Design landing speed is 68.5 m.p.h. Few details and photographs of parts under construction. Aviation, March, 1938, pages 31–32, 8 illus. Western Flying, March, 1938, page 21, 4 illus.

Federal Trainer. "In test flights at Wright Field it was reported that the machine was very maneuverable and although it will not spin involuntarily, it may be spun deliberatley with easy and positive recovery. It is said to be able to clear a 50-ft. obstacle after a run of 50 ft." Long description of the Federal two-place military primary trainer biplane built to Air Corps specifications and now available for export. Aviation, March, 1938, pages 32–33, 7 illus.

Lockheed Booms Ahead. References to the XC-35 stratosphere version of the Electra, to a modification of the Model 14 now being tested by the Army for possible use as a cargo airplane, and to bids for Army orders on a high-speed six-passenger commercial transport. Brief note. Aviation, March, 1938, page 54.

Military Aircraft. Thirty-two American military aircraft available for export are included in the review which covers specifications, performance, construction, standard equipment and instruments used, and blueprints and photographs for each aircraft. Fifteen of the latest aircraft of the U. S. Army and Navy Air Services are shown in photographs with blueprints of the Curtiss Y1A-18, Grumman F3F-2, and Curtiss SBC-3, no details being given for these 15 airplanes. Aero Digest, March, 1938, pages 90–112 (alternate pages), 82 illus.

Miller Two-Place "Zeta." Zeta Z-1 low-wing two-place cabin monoplane (95-hp. Menasco B4) has a maximum speed of 125 m.p.h., the Z-2 (125-hp. C-4 engine) has a maximum speed of 140 m.p.h., and the Z-3 (150-hp. C-4S engine) a maximum speed of 160 m.p.h. Description. Aero Digest, February, 1938, page 70, 1 illus.

New Cargo Plane. Lockheed cargo airplane under construction for the U. S. Army Air Corps competition is an adaption of the Model 14 commercial transport. It has a top speed of 250 m.p.h. and range of more than 2000 miles, and is capable of carrying a load of three 1100-hp. engines in its cargo compartment. Brief note. Aero Digest, February, 1938, pages 90–91.

Plane Previews. Photographs of the Timm twin-engined airplane with tricycle landing gear and two Wright Whirlwind 425-hp. engines, the twin-engined all-wood airplane with two Jacobs engines which has been developed by V. Breese and A. Mankey, and an experimental airplane designed to check out certain theories of the aerodynamics of tailless airplanes and sponsored by Tuscar Metals, Inc. Aviation, March, 1938, page 52, 3 illus.

Private and Commercial Aircraft. Forty-seven American private and commerical aircraft manufactured under Approved Type Certificates, and 26 experimental and other basic types which have not yet received ATCs are covered in the review. Specifications, performance, construction, standard equipment, and instruments, with blueprints and photographs. Aero Digest, March, 1938, pages 40–88 (alternate pages), 146 illus.

Stinson SR9-A. Reliant SR9-A airplane powered with a 225-hp. Lycoming engine. Few details of interior and equipment. Aviation, March, 1938, page 42, 1 illus.

U. S. Army Air Corps' Sub-Stratosphere Lockheed. "Recent test flights conducted by the Air Corps with the Lockheed Sub-Stratosphere plane revealed that the ship attained a maximum speed of 350 m.p.h. over a 220-mile test course, covering the distance in 38 minutes." Construction of the fuselage of the XC-35 and pressure cabin are described. Aero Digest, February, 1938, pages 54–56, 5 illus.

Wendt Series 400 Monoplane. Model W-1 Series 400 two-place high-wing strut-braced cabin monoplane powered with a 90-hp. Warner Scarab Junior engine and having a maximum speed of 140 m.p.h. Description. Aero Digest, February, 1938, page 68, 2 illus., 1 table. Aviation, April, 1938, page 44, 2 illus., 1 table.

Aircraft Accessories

Controls for Operating Flaps. Hydro-pneumatics hydraulic pump and control valves for manually operating split-type trailing-edge flaps or landing gear. Unit consists of double-plunger pump operated by the rocking motion of the operating handle, one complete forward and back stroke of which displaces 5 cu. in. of fluid at 4000 lb. pressure. Some types have automatic control. Short description. Aero Digest, February, 1938, page 83.

Aircraft Controls. M. Waseige advocates centralization of the various devices for generation of pneumatic, hydraulic, or electric energy for the various controls by grouping these mechanisms in an accessories drive box independent of the aircraft engine but driven from the latter. He suggests the use of two universal joints, one at the engine and the other at the relay, connected by a drive shaft. Brief abstract from Revue de l'Aluminium. Automotive Industries, April 2, 1938, page 468.

Aircraft Vibration Testing

Resonance Tests. A. G. Pugsley. History of the development of vibration tests carried out on airplanes, and principles in relation to flutter problems. Aircraft Engineering, March, 1938, pages 73–75, 4 illus.

Air Transportation

Cheyenne Glimpses. Service hangar layout and some of the equipment in use at United Air Lines' overhaul base are illustrated. Aviation, March, 1938, pages 26–27, 14 illus.

Pan American Airways' Alaskan Operations. Pacific Alaska Airways' system of 2125 miles, and the technique required by temperature conditions when the ships have finished their run at Nome. Aero Digest, February, 1938, pages 22, 68, 70, 9 illus.

Flying-Boat v. Super-Liner. R. A. E. Luard. Atlantic traffic in the near future is discussed. Comparisons of flying boats and ships, and operating costs which are given are based on the report of the U. S. Maritime Commission. Data and a cutaway drawing of the projected Consolidated 54-passenger oceanic flying boat are included. Flight, March 17, 1938, pages 256b–256d, 5 illus., 1 table.

How to Make Money Out of Diesels. Something like £2,500,000 a year could be gained on a transatlantic service by using Diesel engines instead of gasoline in a fleet of ten flying boats, according to the calculations given. Aeroplane, March 16, 1938, pages 326–327, 3 illus., 3 tables.

Airships and Balloons

The Hindenburg Disaster. No definite reason for the disaster to the German airship Hindenburg has been discovered by the German Commission investigating. The most probable cause is a combination of gas leakage and the ignition of the resulting gas-air mixture inside the envelope. Abstract of report from Luftwissen, January. Aeroplane, March 23, 1938, page 364.

Stratospheric Record? "What will probably be the largest balloon ever built is to be used this year for a Polish attempt on the ultimate altitude record. Its capacity is to be 135,000 cubic meters and the envelope is of special cold-resisting artificial rubber." The crew hopes to reach a height of at least 30,000 meters (98,500 ft.). Brief note. Flight, March 17, 1938, page 270.

Tests of a Motorized Balloon. Army Air Corps C-6 motorized balloon. Few details. Scientific Am., April, 1938, page 225, 3 illus.

Gliders

Sailplane Development. Squadron Leader G. M. Buxton. Views of the pilot, meteorologist, engineer, and club on soaring. Dynamic soaring; help from dynamic effects; basis for using dynamic effects; progress in soaring up to 1931; developments in England; characteristics of the Kuppe Austrial; present practice in front, thermal, and cloud soaring; characteristics of the best contemporary sailplanes; British King Kite sailplanes; and the possibility of developing a new type of sailplane. Royal Aeronautical Soc., Preprint for Meeting, December 16, 1937, 22 pages.

Abstract of paper and discussion. Flight, December 23, 1937, pages 627–628.

Propellers

Practical Airscrew Performance Calculations. F. M. Thomas, F. W. Caldwell, and T. B. Rhines. Paper and discussion by D. R. Pye, Capt. F. S. Barnwell, H. C. Watts, A. Gouge, F. C. Lynam, C. N. H. Lock, H. Bateman, M. Langley, R. M. Clarkson, and F. Radcliffe, with the author's reply. Journal Royal Aeronautical Soc., January, 1938, pages 1–86, 34 illus., 7 tables many equations.

Lycoming's Hollow Blade. New Type of electrically-welded hollow steel propeller blade. First sizes to go into production will be for military and transport planes. Few details. Western Flying, March, 1938, page 26.

One Prop or Two? G. E. Rice. Development of dual propellers of opposite rotation, and possibilities for their use in the future, especially in regard to the use of two motor gearing hookups arranged so that either motor could drive the duplex propeller unit. Subtitle of the article states that the Army is trying out dual propellers. Western Flying, March, 1938, pages 20, 22, 2 illus.

Record Flights, Meetings, and Shows

Bombers Fly to Argentina. Account of the flight of six YB-17 bombers of the Army Air Corps. A second note entitled "Pacific Air Forces Bolstered," reports transfer of bombers of the Army and Navy to Hawaii and Guam. Western Flying, March, 1938, page 36, 1 illus.

Account of flight to Argentina. U.S. Air Services, March, 1938, pages 13–14, 3 illus.

England—Australia—New Zealand A flight from England to Sydney and Blenheim, N. Z., in 4 days 8 hours and 37 minutes was recently made by A. E. Clouston and V. Ricketts in the Comet powered by standard Gypsy Six Series II engines and D.H. controllable-pitch propellers. Short account of flight. Aeroplane, March 23, 1938, page 349.

Short account and list of equipment used. Flight, March 24, 1938, page 285, 1 illus.

The I. Ae. S. Annual Meeting. A. Klemin. Professor Klemin's account of the meeting and abstracts of papers. Aircraft Engineering, March, 1938, pages 63–69, 5 illus.

New Ships Feature Pacific Show. Plans for the annual Pacific National Aircraft Show which opens in Los Angeles April 2. Western Flying, March, 1938, page 15.

The Show at Chicago. R. Burrows. Some of the aircraft, engines, instruments, radio, and aircraft accessories on display are referred to in a general description of the Show. Western Flying, March, 1938, pages 12–13, 22, 1 illus.

Review of some of the exhibits. U.S. Air Services, March, 1938, pages 26–27, 2 illus.

Technical Notes on a Series of Performances in Commercial Marine Aviation. Record flight of the Latecoere 521 "Lieutenant-de-vaisseau-Paris" across the South Atlantic nonstop over a distance of 5771 km. in 33 hr. 51 min. Preparation of the flying boat for the flight, weight of equipment, fuel consumption, weather forecasting, an account of the flight, radiotelegraphy communications, and other records of the flying boat. L'Aéronautique, January, 1938, pages 2–7, 13 illus.

Aircraft Instruments and Navigation

The Librascope Balance Computer. Individual loads in an aircraft, the total weight of these loads, and at the same time the center of gravity of the loaded aircraft are indicated instantaneously on the dials of the Librascope. Computer designed for the Lockheed 14 weighs less than 5 lb. and measures $9^1/_2 \times 17 \times 1^1/_2$ inches. Description. Aero Digest, February, 1938, page 42, 3 illus.

Ground Apparatus Supplements Training in Instrument Flying. H. S. Pack, Jr. Conditions under which the three systems of orientation developed by the Bureau of Air Commerce and major airlines can be used to familiarize flight personnel with instrument flying in the Link Trainers. The two variations of each procedure given were worked out on the map of the Newark airport range by D. K. Smith and the author. Concluded. Aero Digest, February, 1938, pages 48, 53, 58, 60, 1 illus.

Two DVL Instruments DVL scratch recorder designed to record rapidly changing forces or stresses in various constructional parts. Variations of length are recorded in their natural size by means of a diamond scratch on a suitable surface such as glass and the scratch is magnified. Both short- and long-period scratch recorders are described in detail. Details and drawings are also given for the DVL flight vibration recorder by means of which the oscillations of a wing are photographically recorded on a standard-size cinematographic film during flight. Aircraft Engineering, March, 1938, pages 77–80, 8 illus.

Homing vs. Crabbing Flight. W. R. Weems. Kind of path a homing device causes an airplane to follow, amount the path deviates from a straight line, and the additional time required to make a flight when homing in comparison with that required for crabbing flight. Results of the analysis are presented in nondimensional form. Mathematical derivations are outlined. Aero Digest, February, 1938, pages 34, 36, 7 illus.

Airport Equipment

New Portable Floodlight. Rotax-Harley portable floodlight. An 11-in. 250-watt Harley lamp is carried on gimbals at the top of a 5-ft. column mounted on a three-wheel trolley which carries also dual storage batteries and a gasoline-electric generator set to charge them. Few details. Flight, February 17, 1938, page 170, 1 illus. Aeroplane, February 16, 1938, page 210, 1 illus.

S.I.A.M. Smoke Wind Indicators for Landing Fields. Apparatus recently installed at Bourget is regulated from the control tower and produces a column of very white smoke of an intensity adjustable according to the wind. Emission of smoke may be started or stopped immediately, may be continuous, or may be controlled for signalling by a Morse transmitter. An automatic oil burner supplies hot air into which the smoke-producing substance is injected. Applications suggested include automatic signalling and marking of emergency landing grounds in wartime, since it can be put out immediately. Long description. Rev. de l'Armée de l'Air, December, 1937, pages 1397–1402, 5 illus.

Miscellaneous Equipment

The Deutsche Lufthansa Seaplane Catapult Motorship "Friesenland." In the new catapult ship to be used on the South Atlantic, seaplanes are launched over the stern instead of the bow so that a seaplane lifted from the trailing mat on which it has landed can be placed at once upon the launching rails without being turned. Very long detailed description. To be continued. Engineering, March 25, 1938, pages 321–323, 330, 6 illus. and 14 illus. on supplement plates.

Development of the Aircraft Catapult at the Heinkel Aircraft Plant. K. Schwaerzler. Construction and method of operation of the Heinkel compressed-air catapults are explained, their development described, and possibilities for further development are pointed out. Report of the Ernst-

Heinkel Aircraft Company. Luftfahrtforschung, January 20, 1938, pages 48–53, 13 illus., 1 table.

Fills Tanks from Bottom. Siebenthaler SpeeDee valve unit fills fuel tanks from the bottom instead of the top. One model has a capacity of 150 gal./min. at a fuel hose pressure of 20 lb./sq. in. and the other a capacity of 250 gal./min. at a pressure of 40 lb./sq. in. Description. Aviation, March, 1938, page 49, 2 illus.

A Mechanical Deicer. In the Gosselin design for a deicer the leading edge is covered with a rubber envelope but instead of tubular chambers three rollers operate on rails placed along the leading edge within the covering. The rollers are arranged in a triangle, the central one being the larger. Brief note. Les Ailes, March 3, 1938, page 7, 1 illus.

Army Air Corps Safety Harness. New pilot's safety belt developed at Wright Field is expected to eliminate cranial injuries suffered by pilots and observers in relatively minor crashes. Few details. Aero Digest, February, 1938, pages 80–81, 1 illus.

More about the B.I.F. Further points of aeronautical interest noted during tours of the Birmingham and London Sections of the British Industries Fair. Exhibits of plastics and other materials are referred to and the Rotax Harley landing lamp is illustrated. Flight, March 3, 1938, pages 216–217, 4 illus.

Screw Thread for Aircraft. "Aero-Thread" screw fastening developed for use on steel screws or studs that fasten into aluminum or magnesium alloys. A hard drawn bronze spring wire thread insert is employed between a special round thread groove on the steel stud and a conventional V-thread groove in the light alloy boss. Description. Reference is made to an improved Dardelet self-locking screw-thread profile in another note. Aero Digest, February, 1938, pages 80–81, 1 illus.

Photography

Aerial Photography at Night by Means of the Fairchild Process. R. Maurer. Preliminary research of the U. S. Army Air Corps is mentioned in a long description of the Fairchild equipment and procedure. Rev. de l'Armée de l'Air, January, 1938, pages 100–108, 7 illus.

Model K Skyview Aerial Camera. Aerial camera which can be carried in airplane or automobile is equipped with a Wollensak f 4.5 lens. Brief reference. Aero Digest, March, 1938, page 162.

Engine Design and Research

Characteristics of the G. C. Engine-Cannon Having Reduction Gear, Reversing Gear, and a Double Propeller. Six engine elements are arranged as the cylinders of a revolver, and each element is a small two-cylinder opposed flat-twin unit having valves controlled by rocker arms. Two propellers and reduction and reversing gear are included in the invention. The designer, M. Gadoux, has been technical director of Hispano-Suiza for a number of years. Short description and drawing of the invention, and a few details of a 12-cylinder engine developing 900 hp. at 3600 r.p.m. Les Ailes, March 3, 1938, page 7, 2 illus.

High Supercharging in a C. I. Engine. C. W. R. Smith. Tests undertaken during the years 1931–34 by Ricardo and Company for the British Air Ministry. Test plant and equipment are described and following results discussed: Effects of intake pressures from 1.0 to 2.0 atmospheres, abs., on swirl speed with air at atmospheric pressure and temperature; effect of intake pressure on performance with constant intake temperature at 150° C.; effect of intake temperature on performance with a constant intake pressure of 2.5 atmospheres, abs.; and combustion phenomena. To be continued. Engineer, March 4, 1938, pages 239–241, 10 illus.

Carburetor Icing. R. Sanders. Application of results found in the laboratory to operating conditions in flight, and development of a technique for rational use of the controls at hand to prevent ice formation in the carburetor. Conditions under which ice would form, a simple method of determining when an airplane was in air which might cause ice in the carburetor, the necessity for a carburetor icing warning, and operating rules for reducing the tendency to ice in any weather conditions. S.A.E., Preprint for Meeting March 10–11, 1938, 6 pages, 3 illus.

Driving Gear and Bearing Stresses. J. Geiger. With sudden increase of gas pressure at ignition, especially detonation, considerably higher forces than generally supposed act on the driving gear and bearings of engines. Formulas are derived for the motion of a piston-connecting rod system undergoing elastic deformation under influence of a periodic gas force. Test results are quoted to show the accuracy of the calculations. A.T.Z., December 25, 1937, pages 614–619, 17 illus., many equations.

Engines for Light Airplanes. N. N. Tilley. Light plane engine requirements, history of the development of small engines, the horizontally-opposed engine, power output, ell-head versus valve-in-head engines, accessories, and details of the Continental A-40 and A-50 engines. S.A.E., Preprint for Meeting March 10–11, 1938, 13 pages, 7 illus., 1 table.

Ragoucy Two-Stroke Engine Has Charge Transfer by Pneumatic Shuttle. Shuttle-type slide valve is automatically operated by the pressure difference on its upper and lower surfaces and controls the transfer port into the cylinder. The R-14 aircooled engine shown is arranged for crankcase precompression which is augmented by an auxiliary cylinder with piston making an angle of about 60 degrees with the working piston. Description. Automotive Industries, April 2, 1938, pages 486–487, 1 illus.

Recent Developments in High-Speed Oil Engines. S. J. Davies. Developments since 1931 in regard to combustion chamber design, fuel injection, and practical conclusions concerning the most common form of injection system, and research results on the injection processes in the cylinder itself. To be continued. Institution of Mechanical Engineers paper. Engineering, March 25, 1938, pages 342–344, 4 illus.

The Reduction of Piston Ring and Cylinder Wear. M. O. Teetor. A Ferrox ring sample run on a sample cut from a nitrided steel aircraft-engine cylinder did not scuff nor cold weld to the cylinder and its surface abraded very slightly producing a compound that polished the cylinder sample and at the same time polished itself. Test results with Ferrox and standard ring samples are compared. Development of a wear-testing machine is described in detail. Metal to metal contact between bearing faces of rings and cylinders, the abrasive action, selection of a standard structure of iron for a test-cylinder sample, surface temperature of the ring as an indication of surface disturbance, and determination of the critical scuffing point are discussed. S.A.E., Preprint for Meeting, January 10 to 14, 1938, 8 pages, 1 illus.

Recent Progress in British Engines. British progress in the last three years with reference to increase in power output, metals, fuels, supercharging, cooling, ignition systems, accessory drives, and replacement of the carburetor by fuel-injection pumps. General review. From "The Air Annual of the British Empire" 1938. R.A.F Quarterly, January, 1938, pages 107–112.

The Safety of Modern Aircraft Can Be Considerably Improved By the Use of Flat Engines. A. Gorfinkel. Mechanism of the vibrations of the airplane due to the engine group, the manner in which the engine should be mounted, and advantages of the flat engine in reducing the vibrations of the airplane to a minimum. A flat 12-cylinder engine in two parts with reduction gear at the center of the engine is suggested by M. Banks in a very brief note. Les Ailes, March 10, 1938, page 7, 1 illus.

Technical Notes—What Interests the Service Technique? References only to the following: Sklenar Mawen 9-cylinder radial birotary 150-hp. engine which has been tested 100 hours, a 9-cylinder 350-hp. model which has been constructed, and a double-row 700-hp. engine being designed.

A single-cylinder valveless engine having distribution by sleeves and being tested at the S.N.C.M.

Three Renault, Gnôme-Rhône and S.N.C.M. engines employing injection of gasoline.

Hesselmann engine having gasoline injected directly into the cylinder by the Retel pump.

The different Clerget heavy-oil engines, one of which has 12 cylinders in Vee with three turbo-compressors mounted over each group of four cylinders.

Coatalen 12-cylinder Vee 550-hp. heavy-oil engine with injection spread out over 60° and maximum pressure limited to 60 kg.

Retel two-cycle valveless heavy-oil engine with sleeves having constant pressure of injection.

Hispano-Suiza 12 Y furnished with a turbo-compressor.

Pescara gas turbine with free pistons.

Leduc gas turbine and thermo-propulsive system.

Serrys and S.N.C.M. magnetos with automatically variable advance.

Zenith carburetor having double float chamber giving normal supply of fuel at 87 octane improved by an auxiliary strongly antidetonating fuel proportioned by the second float chamber. Les Ailes, March 10, 1938, page 10.

Torsional Vibration. Li Teng-Ko. New formula giving close approximations for calculating fundamental frequencies and applications to the Tornado Mk. III and Liberty engines. Aircraft Engineering, March, 1938, page 76, 1 illus., 1 table, 6 equations.

Engine Test Stands at the Regional Repair Shops at Bordeaux. P. Hardy. Vibrationless methods of mounting the stands for testing aircooled and water-cooled engines, soundproofing of the control rooms, and insulation of the elements or accessories of the control rooms are described in detail with drawings. A report of the tests made of the noise levels in the control rooms and near the engines is included. Test stands for, water-cooled engines are located in a large building with soundproofed control rooms, but those for air-cooled engines are in the open air alongside of a control building, the propellers being protected by removable cages. L'Aéronautique, January, 1938, pages 11–17, 13 illus., 1 table.

An Engine Test Station on a Mountain. Engine test station established by the Societè Nationale de Construction on Mont Lachat at an altitude of 2100 meters. Very few details. L'Aéronautique, January, 1938, pages 8–9, 5 illus.

New Single-Cylinder Test Installation of the Deutsche Versuchsanstalt fuer Luftfahrt. W. D. Bensinger. Single-cylinder test engine for aircraft-engine tests is described in detail including the adjustable control, braking means and performance measurements, fuel and air measuring installation, cooling means, mechanical and electrical control board, air quantity measurements, and supercharging. A.T.Z., December 25, 1937, pages 621–623, 8 illus.

Performance Characteristics of Engines. P. de Valroger. Rules and standards published by the Service Technique and applying to tests of engines for military aircraft are discussed. Definitions are given for the parameters which characterize the operating conditions of an engine, namely r.p.m., intake pressure, and temperature characteristics, and reasons for their selection are explained. Particular conditions for standard operation on the ground, at altitude, at overload, and overspeed, and with additional torque are considered. L'Aéronautique, Supplement, January, 1938, pages 1–9, 4 illus.

A New Aid to Inspection. Apparatus for inspecting steel aero-engine components combines the advantages of both the Magnaflux and Electroflux instruments. It has been developed jointly by the Engine Department of the Bristol Aeroplane Company and Metropolitan Vickers Electrical Company. Description. Aeroplane, March 16, 1938, page 342, 2 illus.

Engines

Pump or Motor. In both the R.A.D. pump and aero engine designed by Air Commodore J. A. Chamier, two blocks of four cylinders arranged in revolver style, rotate on axes at right angles to each other. Pistons or plungers are made in L-shaped pairs and have no connecting rods or bearings. Each arm of the four double pistons has two motions, a rotary due to its being contained in one bore of the cylinder block, and a reciprocating one caused by rotation of the other block. Engine is cooled by blowing air down the longitudinal fins and through hollow centers of rotating cylinder blocks. The low-powered 8-cylinder two-stroke aero engine has only six moving parts. General verdict was that it wouldn't work but more encouraging reports came from Farnsborough. Factors common to both engine and pump are described with drawings. Flight, March 17, 1938, pages 269–270, 3 illus. Aeroplane, March 16, 1938, pages 327, 328, 3 illus.

Description and results of tests of the pump. Engineering, March 18, 1938, page 314, 3 illus., 1 table.

Fletcher Builds Engine. Fletcher A-460 engine has a total displacement of 460 cu. in. and is estimated to develop 130 hp. at 2100 r.p.m. and take-off power of 144 hp. at 2300 r.p.m. Weight is 364 lb. Few details. Western Flying, March, 1938, page 26.

Fuel Supply for the Engine During Inverted Flight. R. Gauthier. Morane-Saulnier systems for supplying fuel and oil to the engine during inverted flight. Drawings of the installation in the Morane-Saulnier 225 airplane indicate direction of flow during both normal and inverted flight. Long description of the systems and a few details of the circulation of oil in the Morane-Saulnier 341 acrobatic trainers which are equipped with special Renault 4 Pei 140-hp. engines. Rev. de l'Armée de l'Air, January, 1938, pages 89–94, 5 illus.

Gnome-Rhone Engines. Gnôme-Rhône 14-N1 and 14-N7 (950 hp. at 2360 r.p.m. at 3700 meters), and the 14-N11 (920 hp. at 2360 r.p.m. at 3000 meters) 14-cylinder double-row radial engines, and the 18-L1 18-cylinder double-row radial (1300 hp. at 2150 r.p.m. at 1600 meters, 1400 hp. for take-off). Characteristics, performance, accessories, power curves, drawings, and photographs. La Technique Aéronautique No. 146, 1937, pages 230–237, 16 illus.

Hercules Harnessed. Installation of the Bristol two-row sleeve-valve Hercules in its Northrop A.17 flying test bed. Photograph only showing

"how compactly a unit giving over 1300-hp. can be installed." Flight, March 17, 1938, page 270, 1 illus.

New Aeronca Series. Aeronca E-113-C series of two-cylinder opposed engines of 113 cu. in. Model E-113-CD delivers 42 hp. at 2500 r.p.m., and Model E-113-CBD 45 hp. at 2500 r.p.m. Description. Western Flying, March, 1938, pages 26, 28, 1 illus. Aviation, April, 1938, page 42, 2 illus., 1 table.

Sky Motor. Four-cylinder aircooled inverted inline engine developed by Milwaukee Parts, and rated at 60 hp. at 2000 r.p.m. Western Flying, March, 1938, page 28, 1 illus.

Technical Notes. Hispano-Suiza has again taken up the construction of a ouble 12-Y with banks of cylinders vertically in H arrangement. Brief reference. Les Ailes, March 10, 1938, page 10.

Up to 400 Hp. Review of 15 British light aircraft engines between 16 and 400 hp., including the Alvis moderately-supercharged engine giving 375 hp. at 5000 ft. and 425 hp. available for take-off. Particular features, typical installations, photographs, drawings and a table of characteristics and performance. Flight, March 24, 1938, pages 286h, 287–291, 20 illus., 1 table.

Aircraft Engines. Forty-seven basic types of American aircraft engines manufactured under Approved Type Certificates or under I.C.A.N. approval, and seven basic types which have not yet received ATCs are covered in the review. Specifications, construction, accessories, and photographs. Aero Digest, March, 1938, pages 114–140 (alternate pages), 54 illus.

American Engine Specifications. Two-page table covers specifications and performance of 91 aircraft engines. Aviation, February, 1938, pages 64–66, 10 illus., 1 table.

A Crop of British Prototypes. References are made to recent types of Bristol engines including ratings for the Perseus Series VI, VIII, and XII, and power figures are given for the Rolls-Royce Merlin X with two-speed blower. Several new British aircraft are mentioned. Flight, March, 3 1938, page 204.

French Engines. In a catalog of aeronautical products included in the advertising section of this special issue, characteristics and performance are given for 14 aircraft engines. L'Aéronautique, December, 1937.

Franklin AC-150. Aircooled horizontally-opposed four-cylinder engine developed by Aircooled Motors Corporation is rated at 50 hp. at 2400 r.p.m. and weighs 154 lb. Long description. Aviation, March, 1938, pages 34, 42, 2 illus., 1 table.

Gasoline or High-Speed Diesel Engines. Hispano-Suiza 12 Y-21 with a 100-octane fuel developed 1300 hp. during one hour and 1200 hp. during two hours for a weight of 470 kg. or 360 gr./hp. Compression ratio is 7.2. Brief reference to this engine as well as to the Clerget 14-cylinder 900-hp. and Coatalen 12-cylinder V 550-hp. Diesels, and to NACA results with Diesels. General discussion of gasoline and high-speed Diesel engines for aircraft. Les Ailes, March 3, 1938, pages 7–8.

Lycoming O-145. Four-cylinder horizontally-opposed overhead-valve engine develops 50 hp. at 2300 r.p.m. and weighs 150 lb. The crankcase is split on the center line and each half of the case together with each bank of two cylinders is cast in one piece of semisteel. Long description. Aviation, March, 1938, page 35, 2 illus., 1 table. Aero Digest, February, 1938, page 64, 1 illus., 1 table.

M-50. Menasco M-50 four-cylinder horizontally-opposed L-head aircooled engine is rated at 50 hp. at 2550 r.p.m. and weighs 156 lb. dry. Description. Aero Digest, February, 1938, page 60, 2 illus., 1 table.
Longer description. Aviation, March, 1938, pages 38, 70, 3 illus.

Proof of the Pudding. Condition of a D.H. Gipsy Major engine when stripped after 1000-hours running was said to be excellent. All piston rings were free, there was no excess of carbon or sludge, and there had been no serious wear. Most of the components were accepted for reassembly. Short note. Aeroplane, March 2, 1938, page 268, 2 illus.

Ranger 6-410-B. Six-cylinder inline engine rated at 165 hp. at 2450 r.p.m. and weighing 350 lb. dry. Long description. Aviation, March, 1938, pages 41–42, 2 illus., 1 table.

PARTS AND ACCESSORIES

B.G. Spark Plug Service Tool. B.G. M-402 service tool designed for proper forming of spark-plug shell electrodes and for uniform adjustment of B.G. four-point shell electrode spark plugs which have a center electrode tip with concave surface. Description. Aero Digest, March, 1938, page 162, 1 illus.

Coolers and Heaters and Something New in Tanks. Gallay combined oil and coolant radiator used on a "well-known medium bomber." Cupronickel tubes are made from strip in lengths up to 2 ft. and have shoulders on them to permit interflow of cooling liquid. Few details of radiator and of the new quick-refueling anti-surge tank embodying hinged baffles which take up a horizontal postion when filler cap is opened. Flight, March 3, 1938, pages 215, 218, 2 illus.

Electro-Magnetic Fuel Injection. Caproni-Fuscaldo system is said to permit of very high engine speeds giving up to 100 injections per second. It is claimed that fuel quantity injected is always proportional to engine speed and to absolute pressure of the atmosphere, and that mixture ratio remains constant under all operating conditions. The system is illustrated as applied to four-cylinder engines, and is said to be intended primarily for airplane engines. Long abstract from Auto-Moto-Avio. Automotive Industries, March 12, 1938, pages 396–397, 4 illus.

Engines Coupled. Unitwin Power, a new method of gearing developed by Lockheed and Menasco, whereby tow-in-line engines are coupled together in a side-by-side position to drive one propeller. Either engine may be operated independently without any drag being transmitted from the inoperative engine. Brief note. Aero Digest, February, 1938, page 96.

Starter for Light Aircraft. Criley-Norman starter for aircraft engines up to 90 hp. is a three-sectioned device using hydraulic brake fluid throughout. Injector, consisting of cylinder, piston and driving screw, is located in the cockpit and is used as the energizing agent for the "Hydro Motor" installed on the engine. Third unit is a hydraulic pneumatic cell. Short description. Aero Digest, March, 1938, page 162, 1 illus. Aviation, March, 1938, page 48, 1 illus.

Reaction Propulsion

Thermo-Propulsive Nozzles. Gas turbine designed by M. Leduc and now under construction develops 200 hp. and weighs 32 kg. A centrifugal compressor with blades compresses the air in a circular chamber where the fuel is injected and ignited and the gases are expanded in a reaction turbine. This system is used directly for propulsion without a propeller. Opinions of G. Caproni on reaction propulsion are quoted and a short description given of the Leduc gas turbine. Drawings illustrate the Leduc gas turbine and the thermo-propulsive airplane. Abstracts from La Conquête de l'Air and La Technique Moderne. Les Ailes, March 10, 1938, pages 7–8, 2 illus.

Fuels and Lubricants

Aircraft Fuels of High Octane Rate. W. H. Hubner and G. Egloff. Advantages of 100-octane fuel over 87-octane; comparative octane values and physical properties of isopentane, isooctane, aromatic hydrocarbons, isopropyl ether, ketones, and alcohols; blending values and lead susceptibilities of high-octane fuels; antiknock compounds; and comparative data recently obtained with various types of high-octane fuels by the Army Air Corps, A.S.T.M.-C.F.R. motor, and modified motor methods. Oil & Gas Jour., March 31, 1938, pages 103–104, 106, 108, 112, 11 tables.

The Effect of Oil Characteristics on Wear in Aviation Engines. O. C. Bridgeman and M. L. Leidig. In addition to compounding for wear control, it may be necessary to compound lubricants for reduction in ring sticking, for high oiliness in master-rod bearings under power-diving conditions, for extreme-pressure characteristics in connection with reduction-gear lubrication, and for protection against corrosion and rusting. Test apparatus must be designed specifically for each application, simulating service conditions as closely as possible and tests must be made on particular metal combinations.
Effects of surface composition and structure, surface finish, speed, load and temperature in relation to lubricant characteristics and wear are considered, and the effect of lubricant characteristics in reducing wear are discussed. S.A.E., Preprint for Meeting, January 10 to 14, 1938, 8 pages.

Production of Aviation Fuels by High Pressure Hydrogenation. C. L. Brown and J. A. Tilton. Some octane-number test results obtained by the A.S.T.M.-C.F.R., U. S. Army Air Corps and British Air Ministry methods on clear and leaded hydrogenated and virgin aviation fuels are given. Properties of the hydrogenated naphthas and their blends with high-octane-number blending agents are discussed. General method of operation employed at the Baton Rouge plant of the Standard Oil Company of Louisiana for production of high-quality hydrogenated aviation fuels is also described. Oil & Gas Jour., March 31, 1938, pages 74–77, 8 illus., 8 tables.

Engine Lubricator. Pylonol product used for keeping aircraft engines in better running condition is an oil concentrate mixed with a gas-oil carrier which evaporates with heat. The remaining 75 per cent of the solution does not evaporate and is said to stand 200° more heat than conventional lubricating oils. The product may also be mixed with gasoline or injected into the intake manifold to loosen valves and pistons. Brief reference. Aero Digest, February, 1938, page 83.

Shell Broadens Its Research in New Laboratories. J. Geschelin. Equipment of the Wood River Laboratories of the Shell Petroleum Corporation is described with references to research being undertaken on fuels and lubricants. Automotive Industries, March 12, 1938, pages 382–386, 10 illus.

Metals

Riveting Methods and Rivet Equipments Used in the German Light Metal Airplane Construction. W. Pleines. German and American practices in regard to materials for rivets used in aircraft construction are compared. Reference is made to new German materials and development of rivet-metal alloys for which hardening and hardening rate at room temperature is retarded in a higher degree than for alloys used today. Differences between German riveting methods in aircraft construction and those in general engineering practice are pointed out. Various shapes of riveted joints in light metal airplane construction and working methods in use in Germany are described. Application and handling of riveting and drilling tools, and machine riveting are also considered. Royal Aeronautical Soc., Preprint for Meeting, March 3, 1938, 20 pages.

The Fatigue Strength of Thin-Walled Tubes for Aircraft Structures in Unwelded and Welded Condition. H. Cornelius and F. Bollenrath. Effect of welding practice on thin-walled tubes. Particular attention is given to the effect of heat treatment after oxyacetylene welding on the strength of seamless chrome-molybdenum-steel tubes (28-mm. external diameter and 1-mm. wall thickness). When subjected to repeated bending. Collection of data from various papers. DVL report. Luftfahrtforschung, October 20, 1938, pages 520–526, 12 illus., 8 tables.

When Weight Pays. Heavy Alloy, a new alloy of the General Electric Company in England, is being used to balance crankshafts of aero engines, for centrifugal clutch plates which provide the slipping mechanism for super charger drives, and for balance weights on controllable-pitch propellers. Tensile strength and yield point are comparable with those of alloy steel. Thermal conductivity is twice that of steel, but coefficient of expansion about half. Properties, process of manufacture, and micrograph of weld. Aeroplane, March 23, 1938, page 374, 1 illus.

Aircraft Radio

Aero Radio Digest. First issue—Bendix Type MN-12A radio direction finder with two types of loop. Bendix RG-2 airport receiver. RCA right-angle drive unit for mechanical remote-control shaftings used in aircraft radio. Universal aircraft directional type microphone. Western Electric Model 25A transmitter for private pilots and Model 13CA transmitter for high- and low-frequency work. United Air Lines' static detector which detects and measures static charges encountered by aircraft in flight.

Second issue—Aerovoice D-6 receiver for private aircraft. General Electric small radio transmitter capacitors for use under severe conditions of humidity and temperature. Bendix TG-8A 25-watt low-frequency airport transmitter. Westinghouse miniature power level indicators for measuring evels of audio-frequency signals. Aerovoice D-40 36-watt transmitter for private aircraft. Brief accounts of the A.I.E.E. symposium on radio aids to air navigation and communications, and of the installation of the Air Track at Alleghany County Airport, Pittsburgh.
Short descriptions of radio apparatus. Aero Digest, February and March, 1938, pages 78–79 and 34, 37, 14 illus.

Aircraft Radio. United Airlines electrostatically-shielded loop of large dimensions to be used in ground stations. Radio-Navimeter, navigating calculator for radio direction finders, designed at the L.M.T. Laboratories, Paris. Shreve-Aero and the AR-30-W transmitters for the private flyer. Western Electric Model 25A midget transmitter weighing 22 lb. and a larger transmitter, the type 13CA which covers both long and short waves. Short descriptions. Aviation, March, 1938, pages 44, 47, 4 illus.

Radio Emergency Procedure. H. W. Roberts. Recommendations for a standardized radio emergency procedure for commercial aircraft to promote safety. The author advocates a radio operator-navigator in addition to two pilots, improved types of aircraft radio direction finders, enforcement of standardized rules, double complement of transmitting equipment on aircraft, location of ground direction finders for aircraft at strategic airports, and

qualified pilots on call at ground stations. Aero Digest, March, 1938, pages 27, 160–161.

Radio Network and Practice of Pan American Airways. H. W. Roberts. Typical Pan American radio apparatus employed on the ground and in the air is described. Pan American radio network and practice are compared with domestic practice, and certain features are recommended for adoption by domestic airlines. Aero Digest, February, 1938, pages 48, 50, 4 illus.

Another American D/F Development. Simon Radioguide operated on the ratio principle in which two loops are employed, the signal strength ratio between them indicating actual bearing of the transmitting station in degrees relative to fore-and-aft axis of the airplane. First unit has been installed in the Bureau of Air Commerce's Lockheed Electra. Short note. Flight, March 17, 1938, p 268.

New Safety for Liners of the Air. R. Andrews. Safety devices briefly referred to include: a recently tested glass nose for an airplane through which homing radio signals flowed without interruptions; flaps; flight analyzer; deicers used on TWA airplanes; weather forecasting services; radio direction finder developed by TWA; and Bureau of Air Commerce radio developments. U.S. Air Services, March, 1938, pages 22–23, 36.

Television for Bombers? Experiments with television for use on bombing aircraft are referred to. It is claimed that a set with which J. L. Baird has been experimenting in an airplane at Crystal Palace enables pilots to see on a ground-glass screen an objective 50 to 100 miles away. "No technical details are available, but information seems to imply the presence of a transmitting station at the objective which seems a little odd." Mr. Baird is on his way to Australia to continue experiments. Brief reference. Flight, March 24, 1938, page 299.

Meteorology

Bombing of Hail Clouds from Aircraft. Both percussion and smoke bombs have been used in the bombing of hail clouds. In the smoke bombs designed by Capart a radio-active filling is heated to 700° by combustion of the explosive leaving a highly ionized trail of smoke as the container descends. This trail of smoke causes, either flow towards the earth of electric charges accumulated in the cloud, or a thunder clap, the shock of which facilitates precipitation of the hail. Other means for the dispersion of hailstorms by use of artillery are discussed. Les Ailes, January 6, 1938, page 7.

Yankee Forecasts for Soviet Flyers. E. M. Vernon. An account of the weather forecasting service furnished from American sources to the Soviet flyers, especially the service rendered the searching expedition of Sir Hubert Wilkins. Chart shows location of weather forecasting stations between 60° and the North Pole. U.S. Air Services, March, 1938, pages 16–18, 1 illus.

Aeronautical Industry and Production

1938 Accessories on Parade. Manufacturers of accessories and equipment for airplanes, engines, airways, and airports are listed with photographs of some of their products. Aviation, February, 1938, pages 30–34, 78, 51 illus.

Aero Chamber Survey Sets '37 Deliveries at $115,000,000. Statistics for sales of airplanes, aircraft engines, and spare parts in 1937, which broke all peacetime production records, and survey conducted by the Aeronautical Chamber of Commerce of America showing that the production possibilities of present plants had never been even approached. Abstracts. Aviation, March, 1938, page 53.

Aircraft Manufacturers. Directory of American aircraft and engine manufacturers listing executives and location of plants. Aero Digest, March, 1938, pages 38–39.

Alphabetical Industry Directory. Names and addresses of firms making up the aeronautical manufacturing industry of the United States. Aviation, February, 1938, pages 81–98 and 144–158 (alternate pages).

Curtiss Airplane Production. Methods in use, equipment, and factory layout. Aero Digest, February, 1938, pages 26–27, 3 illus.

Manufacturers of Accessories and Parts. Index and directory of sources of supply of accessories and special parts for aircraft and aircraft engines in the United States. Aero Digest, March, 1938, pages 142–158 (alternate pages).

Plant Expansions. Additions to the Barkley-Grow and Lockheed plants. Brief references. Aero Digest, February, 1938, page 96.

Propeller Company. The Freedman-Burnham Company has been formed in Cincinnati to manufacture a controllable-pitch propeller that can be adapted to engines of different designs. Brief reference. Aero Digest, February, 1938, page 96.

Production and Deliveries of Airplanes and Engines. Production statistics for commercial and military airplanes and engines for the year 1937 compared with that for 1936. Western Flying, March, 1938, page 32, 1 table.

Manufacturing Company Formed. Allied Aviation Corporation has been formed to manufacture aircraft engines and accessories. Patent rights have been obtained on the French Monsoon engine and the British Claudel-Hobson carburetor. Brief reference. Western Flying, March, 1938, page 34.

Air Forces

Australia

The Royal Australian Air Force. Total authorized establishment of the Air Force consists of 250 officers, 90 cadets, and 2250 airmen in the Regular Air force, and 85 officers, cadets as required, and 314 airmen in the Citizens Air Force. Organization, personnel, training, equipment, operations, development, and role in Australian Defence. R.A.F. Quarterly, January, 1938, pages 2–8, 3 tables.

Canada

The Royal Canadian Air Force. Air Force consists of a Permanent Force with a strength of 195 officers and 1498 airmen and a Non-Permanent Force with a strength of 118 officers and 946 airmen. Discussion covers briefly: four possible developments in the defense of Canada; development and duties of the Air Force since the war; variety of climatic and topographic conditions; training, depots, squadrons, and stations of the Permanent Air Force;, and squadrons of the Non-Permanent Air Force. R.A.F. Quarterly, January, 1938, pages 10–14, 4 illus. on supplement pages, 2 tables.

Foreign News in Brief. Present strength of the Royal Canadian Air Force totals 167 officers and 1489 other ranks. Deliveries of 18 Westland Wapiti fighters have been made to the Air Force, and four Wasp-powered Noorduyn Norsemen have been ordered for training in bombing, navigation, radio communication, and spotting. Brief references. Aero Digest, February, 1938, pages 99–100.

Great Britain

Air Estimates Introduced. Estimated British expenditure this year, including £30,000,000 to be defrayed from the Defence Loan, amounts to £103,500,000. Extracts from Lt.-Col. Muirhead's speech in the House of Commons dealing with planning, policy, program, research, and training. Parts of the debate demanding an inquiry into R.A.F. administration (which was refused) are included. Extracts from G. Shakespeare's speech introducing Navy Estimates are also given. For the Fleet Air Arm just over £ 5½ millions have been provided through a grant to Air Votes. Flight, March 24, 1938, pages 300–301, 309.

Extracts from Lt.-Col. Muirhead's speech dealing with planning, instruments, production, research and development, personnel, Auxiliary Air Force, flying training, airports and buildings, meteorology, and civil aviation.

Long extracts from the Debate following refer to the Opposition views calling for an inquiry into the Service side of the Air Ministry, and give the answers of the Prime Minister and others. A third article reports the House of Lords debate on the Cadman report and o her Air-Ministry problems. Aeroplane, March 23, 1938, pages 351–358.

The White paper on defence. References to the Royal Air Force, included in the Defence Statement issued by the Biritsh Government, cover supply of equipment, training of personnel, new pilots, and increases in strength of the Home Defence (Metropolitan) Air Force. Brief note. Extracts from the Debate in the House of Commons on National and Imperial defense. Aeroplane, March 16, 1938, pages 341, 324–325.

The Cadman Civil Aviation Inquiry. The "really serious defect disclosed by the Cadman enquiry has very little to do with civil aviation but everything with the re-equipment of the R.A.F. . . . the Government flatly refuses to act on this particular aspect of the Cadman Committee's Report." Editorial comment.

A special digest of the Committee's recommendations and the government's ruling is given including: the European air-service modifications, changes in the Air Ministry personnel, a director of civil research and production, criticism of Imperial Airways, and a larger subsidy for civil aviation. The Committee considers that "In certain developments, such as pressure cabins, automatic blind-landing equipment, anti-static devices, instruments, and radio, this country was not keeping pace with the U.S."

Opinions of many authorities on the Report are quoted in a preceding article entitled "What Aviation's Leaders Think of the Cadman Report." Flight, March 17, 1938, pages 247–249, 260–266, and 250–253.

Mr. Grey comments on the Cadman Committee's Report on Civil Aviation and on the decisions made by the Government regarding them. He considers that the only point on which the Committee seems to have gone badly astray is its recommendation that all matters of research, supply and production should be taken away from Serving Officers on the Air Council and made part of the Department of the Secretary of the Air Ministry. Aeroplane, March 16, 1938, pages 331–336.

Debate in the House of Commons on the Government's observations on the Cadman Committee report. Aeroplane, March 23, 1938, pages 366–367.

Overseas Commands. Operations at Aden, Iraq, Middle East and India. Brief notes. R.A.F. Quarterly, January, 1938, pages 89–92.

Royal Air Force Expansion. Since April 1, 1935, some 3850 pilots have been selected and approximately 3500 have already completed or are in the course of training. Number of airmen total 25,200. About 4840 boys are undergoing training at Halton and Cranwell as aircraft apprentices and elsewhere 960 as boy entrants. Total strength of the force is approximately 60,500. Twenty-five new stations and armament training camps have been opened. Brief note. R.A.F. Quarterly, January, 1938, page 89.

A New Royal Air Force Station. Details of the R.A.F. station at Harwell. Aeroplane, February 16, 1938, page 192.

No. 214 (Bomber) Squadron. Major F. A. de V. Robertson. Work and equipment of the squadron, and a review of its war history. Flight, March 3, 1938, pages 204a-204c, 204g, 204h, 6 illus.

Record Intake of Pilots. The 1750 pilots required by the Royal Air Force during the present year ending March 31, were all obtained by the end of January. Approximately 1300 have been accepted from candidates from civil life and the balance, in accordance with normal policy, are selected volunteers from serving airmen in the R.A.F. Total number of pilots entering since the expansion began in 1935 now exceeds 4500. Brief note and editorial comment. Flight, March 3, 1938, pages 211, 195.

An Unconvincing Effort. Demonstration of practice bombing at Porton range, and some facts about the bombing range of the Royal Air Force. Aeroplane, February 16, 1938, pages 192–193.

Italy

Events Abroad—Italy. Account of Sicilian maneuvers taking place last August. R.A.F. Quarterly, January, 1938, pages 94–96.

Italian Aircraft Carriers. Italy intends to keep her decision not to construct aircraft carriers. The extraordinary increase in speed, range and carrying capacity of modern aircraft has diminished the usefulness of the aircraft carrier. Brief note referring to Italian Navy Estimates introduced by Admiral Cavagnari. Aeroplane, March 23, 1938, page 349.

Italy's Air Power. Italy has been the first to form homogeneous units stronger than the group and by Spring they will be in a position to pass from the air Division to the air corps, of which two would be formed as an experiment. The air corps, incorporating a number of divisions of bombers and fighters, would contain hundreds of machines which could in 24 hours be transferred from one sector to another. Today such masses are operating on the formula of one-ton load of bombs, a range of 1250 miles and a speed of 250 m.p.h. Quotations from General Valle's speech introducing the Italian Air Estimates. Aeroplane, March 23, 1938, page 348.

Japan

Eyesight and Promiscuous Bombing. Optometrist who has tested the eyes of a number of Japanese comments on the prevalence of myopia among them. He considers that unless Japanese aviators and artillerymen wear glasses there would be very few capable of recognizing flags from a distance. Short letter. Aeroplane, February 16, 1938, page 214.